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LEAD POISONING BY WATER, AND ITS PREVENTION.

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[*August 20, 1920.*]

While much has been written under the same title as this paper, experiences in practice, during the last few years, have brought forth facts which have not been published in water-works journals, and which throw new light on the whole problem.

HISTORICAL.

It is no new statement, that certain waters take up enough lead from service pipes to cause lead poisoning (plumbism) when drunk by certain susceptible persons. Lead poisoning was first noticed by the ancients. Hippocrates was well acquainted with it. Galen,† the Roman physician, wrote an account of the disease and described the harmful action of water on the large, lead service pipes which were then used in Latin cities. Vitruvius,‡ an architect who was a contemporary of Augustus Cæsar, forbade, as did others, the use of lead pipe for conveying water.

In the middle ages lead poisoning was quite common, owing to the ancient custom of conveying waters to public fountains through leaden pipes. The only reason why it was not more prevalent was because most of the then civilized world used comparatively hard waters, which had only a slight action upon lead.

In Great Britain, in the early part of the nineteenth century, a number of cases were noted, particularly at Tunbridge Wells; and in 1842, at Lowell, Mass., a joint special committee reported upon the numerous cases which had occurred in that city as a result of using lead services with ground water. In 1848,§ Louis Philippe and his family established themselves on the estate of Claremont in England. For thirty-three years this estate had been supplied through a leaden pipe from an open spring

* Of Weston & Sampson, Consulting Engineers.

† De Compositione Medicamentorum, Secundum Locos, Vol. XII.

‡ De Architectura, Liber VIII, Cap. 6, "De Ductionibus Aquarium."

§ Sedgwick — JOURNAL N. E. W. W. Assn., XV, 316.

of great purity, two miles away. No bad results had been noticed by previous occupants, but 34 per cent. of the newcomers, including Louis Philippe and members of his suite and servants, suffered severely from lead poisoning. It was found upon investigation that, just prior to the coming of the French occupants, the spring, previously open, had been covered with an iron dome, thereby preventing the escape of the excess of carbon dioxide gas, and thus favoring the solution of the lead from the long pipe line which conveyed the water to the residence.

In 1848, when the introduction of the Cochituate water into Boston was under discussion, Professor Hosford,* of Harvard College, made a series of experiments and concluded that lead pipes could be used with safety for the conduction of this water. He found that although some corrosive action occurred when the pipe was new, a coating would soon be formed, which would be to such a great degree insoluble and impenetrable, that after a short time the action of the water would be practically nothing.

In 1870, Report of the Massachusetts Board of Health, it was stated 170 correspondents of the Board, in as many different places, reported 41 cases of either lead colic or lead paralysis. Most of these were explained by the drinking of well or spring waters drawn through lead pipe.

In 1871, in the second report of the Massachusetts State Board of Health, there is an interesting treatise on the general subject, including an experimental study into the effect of various waters on lead, by Prof. William Ripley Nichols, then associate professor of chemistry at the Massachusetts Institute of Technology. Professor Nichols felt justified in asserting that —

(1) The Cochituate water which has passed through lead pipes is never absolutely free from lead.

(2) That, when the water is first introduced into the pipes, there is more action on the pipes, as far as contamination of the water is concerned, than subsequently, but that after a few days' service the quantity of lead in the water is practically very small.

(3) That there is always more lead in the water after it has stood for some hours in the pipes than when it is allowed to flow freely.

(4) That when the water passes through a lead-lined tank it will be likely to contain in solution or suspension a more considerable quantity of lead salts, from the fact that the lead is corroded more rapidly on the sides of the tank at the surface of the water. Moreover, in such tanks there is generally a considerable extent of surface of contact between solder and the lead.

(5) That in the introduction of water into the pipes, the first effect is the tarnishing of the brightness of the lead due to the formation of oxide or suboxide; that there begins to form, almost immediately, a coating consisting on the *outside* of a brown and, at first, rather loose deposit (the color of which is not due to iron-rust as is ordinarily supposed, but to organic matter), and *underneath* of a white deposit composed mainly of

* Boston City Documents, 1848, Nos. 18 and 32. Also Proc. Am. Acad. II, 64.

carbonate of lead; that this coating increases with time in firmness and also in thickness, but that the rate of increase is so slow that practically the pipes used for conveying *cold* water do not wear out and become unserviceable, excepting from some accidental circumstance, as the freezing of the water; or, as is often the case where the pipes are laid under ground, from corrosion from the outside, or from a cause immediately to be mentioned. That, however, the pipes even under ordinary conditions would eventually wear out, I have no doubt, as there seems to be no limit to the action. I have, indeed, a specimen of a pipe which, being in contact with cold water only, for a period of fifteen years, was so corroded in the vicinity of the solder-joint as to be eaten through, and along the pipe there is a thick coating consisting almost entirely of carbonate of lead (with organic matter, a little carbonate and sulphate of lime, and a trace of oxide of iron) which has penetrated the pipe in some places to the depth of $\frac{1}{15}$ of an inch and more. There is one other circumstance contributing to the wear of cold-water pipes which is not to be overlooked. The water is delivered in many cases under such a pressure that the pipes tend continually to expand. The effect of this is often to strain the pipes so as to form longitudinal seams or grooves of greater or less length and, the corrosion taking place under such favoring circumstances more rapidly, sometimes extends through the pipe, which is thus rendered unserviceable by a combination of chemical and mechanical action.

(6) The pipes used to convey *hot* water are corroded more or less rapidly, a deposit similar to that in the cold-water pipes being formed, and the corrosion manifesting itself more decidedly in the vicinity of the solder points, and where the pipe is sharply bent. Whether the iron-rust, coming from the *water-backs* in which the water is heated, contributes to produce this effect, I am not prepared to say. The disarrangement of the particles of the lead and the change in its mechanical structure brought about by the alternate and unequal contractions and expansions to which it is subjected, must present more favorable opportunity for the corrosive action due simply to the passage of the water through the pipes.

Further study and modern physical chemistry have but explained the facts which this brilliant investigator established. Furthermore, his belief regarding the effect of the presence of various salts has been confirmed absolutely. One statement of Professor Nichols has a most familiar sound to the water-works man. It is: "The pipe in use is much inferior in strength and durability to that formerly in use."

During Professor Nichols's life, modern public-health engineering came into existence, and from then on more attention was paid to the poisonous effects of plumbo-solvent waters particularly in those regions where soft, peaty waters or waters containing much free carbon dioxide were in general use.

In the 1883 edition of Professor Nichols's *Water Supply* he describes experiments with various waters, using lead strips in some cases, and in one particular case a coil of $\frac{1}{4}$-in. lead pipe 100 ft. long. He makes the interesting statement that, "while in most waters the action on lead practically ceases, it probably never ceases absolutely."

Following Professor Nichols, the Massachusetts State Board of Health pursued its studies in this important field. In the report for 1886, a typical

case of lead poisoning is described, and its connection with a drinking water supplied through lead pipe was proved.

In 1898, Mr. H. W. Clark, chemist of the Board and a distinguished member of this Association, reported the results of his two years of exhaustive investigation. In Massachusetts, seventy-one, or 25 per cent., of the municipalities were supplied in whole or in part through lead (or lead-lined) services; in ten of these lead was used exclusively, and in fourteen others over 50 per cent. of the services were lead.

At that time, cases of lead poisoning were reported to exist in Fairhaven, Kingston, Lowell, and Milford, but the disease was not believed to have developed elsewhere. Exhaustive experiments by Mr. Clark showed that the waters supplying these four places dissolved more lead than the other waters experimented with. These four were ground waters, — clear, colorless, soft, nearly free from organic matter, — and contained oxygen and carbonic acid. Other ground and surface waters contained either too little oxygen and carbon dioxide to dissolve or erode lead, or so much organic or mineral matter that protective coatings were formed inside the service pipes.

In the 1900 report, Mr. Clark (with Fred B. Forbes) published additional results, which re-emphasize the importance of carbonic acid with or without oxygen in making waters plumbo-solvent.

In other states and in Great Britain, parallel studies had been carried on, particularly by Dr. A. C. Houston,* who examined numbers of waters which contained peaty acids and dissolved lead rapidly.

The report of the local government board for 1908 names forty-eight towns which are supplied with plumbo-solvent waters.

In Germany the subject received more or less attention. Spitta† states that certain cities are supplied with plumbo-solvent waters, *e.g.*, Dessau, Emden, Frankfurt, Kottbus, Offenbach, Oldenburg, and Wilhelmshaven.

In some of these, notably Dessau and Wilhelmshaven, lead poisoning had been very prevalent.

Causes of the Action of Water on Lead.

The causes of the action of water on lead may be deduced from the above descriptions of the works of Nichols and Clark. More recently they have been elucidated by Houston (*loc. cit.*) and this year with special reference to the Birmingham (England) supply by Liverseege & Knapp.‡ In 1910 the writer§ presented to this Association a theoretical discussion of the phenomena of corrosion of the metals used for service pipes.

Two distinct actions are now recognized: (1) Plumbo-solvency, or true solution; (2) erosion.

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* Supplements to Reports of Local Government Board, 1900–1902.

† Arb. ans d. Kais. gesundhertsamb.

‡ Journ. S. C. I., *39*, 32 T.

§ Weston, The Corrosive Action of Water on Metals, this Journal, XXIV, 559.

Plumbo-Solvency.

By plumbo-solvency is meant the dissolving of the lead, — usually in carbonic or other acid. By erosion, a term introduced by Dr. Houston, is meant the action which a faintly alkaline or neutral water containing oxygen has on lead. Where erosion takes place, scales are formed on the surface of the metal. These scales fall off, leaving a fresh, bright surface open to attack. Lead so eroded imparts a turbidity to the water.

The cases cited above, where lead poisoning has occurred, were mostly those where the lead was truly dissolved in the water. Other cases are the soft, peaty water supplies as used in Northern England. Dr. Houston* states that out of 58 reservoirs examined, 35 yielded acid waters which were plumbo-solvent. Recent experiments by the writer with solutions of peat in distilled water have shown that this action is due to the peaty acids and not to some other agent. Moist, peaty soils are invariably acid, and the waters which drain from them are usually acid also. The acids in these waters have been manufactured in the peat by bacterial fermentation. The acid is not increased on storage. It decreases, but slowly, when the water is stored in a stoppered bottle. Exposed to the air, however, the peaty matter decomposes; the acids decrease, and are ultimately oxidized.

This action of peaty waters is quite rapid. My own experiments show that it is dependent upon the degree of color or the amount of peat.† Wm. Ackroyd‡ has shown that the plumbo-solvency of peaty waters varies with the acidity.

Effect of Acidity on Plumbo-Solvency.

Time, Hours.	Acid as H_2SO_4 (P.P.M.)	Lead Dissolved (P.P.M.)
1	2.9	0.3
1	3.0	0.57
1	2.9	0.25
0.25	13.4	7.1
0.25	15.9	9.5

Ackroyd does not distinguish between peaty acids and carbonic acid.

Clark (*loc. cit.*) showed that infusions of hay exerted little action on lead, but when the same had decomposed and produced carbon-dioxide gas, the action was rapid. The peaty acids, however, certainly dissolve lead. They may not be important constituents of hay infusions.

Another type of plumbo-solvent water is that which drains through certain rocks, particularly those containing pyrite or other compounds of sulphur.

The above, with the soft, spring, or well waters containing large amounts of carbon dioxide, are the three principal types of plumbo-solvent waters.

* Interim Report, Local Government Board, 1895.

† See page 247.

‡ J. S. C. I. (1899), p. 164, and (1900) p. 1130.

Erosion.

Certain soft waters, containing less than 30 p.p.m. of free carbon dioxide, which will not dissolve appreciable amounts of lead, produce erosion. Usually such waters have alkalinities of less than 15 p.p.m. If a bright piece of lead be exposed to a water of this type, contained in an open vessel, the whole surface of the lead is eroded, and a precipitate forms which falls to the bottom of the vessel, leaving the surface of the metal quite bright, but mottled.

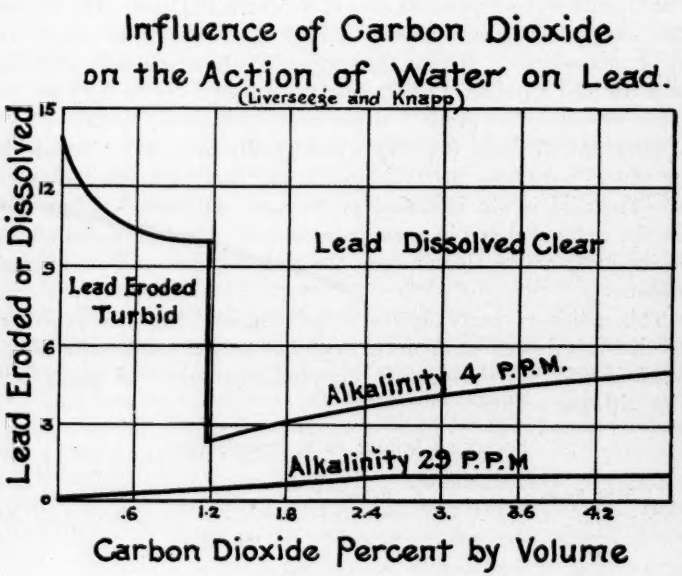

FIG. 1.

Waters of this group, which have an alkalinity of 15 to 25 p.p.m., rarely erode lead. Such waters do show some action on lead, but it is usually slight, and more or less crust is formed on the surface of the metal, usually on the upper surface of the pieces exposed. This crust usually consists of basic lead carbonate.

Waters of the same group, having an alkalinity higher than 25 p.p.m., usually produce a protective coating upon the surface of the metal, which prohibits further action of the water.

Erosion readily occurs in waters which contain no carbon dioxide and is due to the action of oxygen in the presence of water. Liverseege and Knapp (*loc. cit.*), state that an increase in the carbon dioxide from 1 per cent. to 2 per cent. by volume (from 20 to 40 p.p.m.) causes a sudden change from erosion to plumbo-solvency (Fig. 1). Erosion, therefore, is

largely due to the action of water and oxygen, and the degree of erosion is dependent more upon the degree of alkalinity of the water than any other factor.

Rideal* states that lead appears to be most soluble in waters containing oxygen and carbon dioxide in the ratio of 1 : 2.

In cases of peaty waters, the acidity to lacmoid, of the sample tested, usually determines whether or not the water will act on lead. With the reaction to lacmoid in view, waters may be divided into two classes: (1) Acid, plumbo-solvent, and non-erosive; (2) slightly alkaline or neutral, non-solvent, and erosive.

Acid waters are not necessarily those which contain no alkali in the form of carbonates. Plumbo-solvent waters which contain peaty acids or

FIG. 2. SHOWING PROTECTIVE COATING ON BOSTON SERVICE PIPE.

carbon dioxide may contain considerable alkali in the form of carbonates and still exert a solvent action upon lead. It all depends upon the relative potentialities of the acid and alkaline elements of the water. These factors will be discussed beyond under " Prevention of Action " (p. 248).

Fig. 2 illustrates the action of seven waters upon lead. One set of tubes shows the result of one, and the other set of seven days' action. Ten cubic centimeters of each sample were placed in open test tubes in which were afterwards placed pieces of bright sheet lead, about 1.0 in. by 0.5 in. by 0.2 in. (Area 10.1 sq. cm., or 1.57 sq. in.) This is the method of Dr. Houston as modified by Liverseege and Knapp.†

* Water Supply, 1915, p. 50.

† "*Method of Performing the Erosion Test.*" The method adopted in all experiments where the details are not specified is that outlined by Dr. Houston:

" Commercial sheet lead in strips ¾-in. wide and about ¼-in. thick (one square foot weighs 4.3 lb.) is scraped bright with a plumber's shave hook, and cut into lengths of 1 in. Each piece is rubbed with a

The waters used in the preparation of Fig. 2 were as follows:

	Characteristics.	Lead Found, P.P.M., after 7 Days.	1 Day.
Boston tap water.....	Soft, low-colored surface water	158	65
Distilled water.....	Nearly pure water	540	182
Still Poland water.....	Nearly pure spring water	82	44
Charged Poland water.....	Nearly pure spring water plus CO_2	154	90
Vichy (Célestins) water.....	Alkaline plus CO_2	32	10
Distilled water plus peat extract* — color 150.....	Peaty	41	6
Boston tap water with peat extract* added, color 150.....	Ditto plus some alkali	25	2

During the past few months, various waters have been tested according to Dr. Houston's method, with the results given in table on opposite page.

In the table it will be noted that erosion occurred only in those cases where the alkalinity of the water was low. Waters of the type of the Boston tap water erode considerable lead, but the further action of these waters upon lead surfaces is prevented by the formation of protective coatings. Waters like that from the well at Camden, which contain 199 p.p.m. of free carbon dioxide, fail to attack lead appreciably because of their high alkalinity.

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clean duster kept for the purpose, and dropped into the water without touching with the fingers. Test tubes 6 in. by ¾ in., reserved for this purpose only, are washed with tap water and allowed to drain.

"Ten cubic centimeters of the water is poured from a cylinder into the test tube, and the strip of lead polished with a cloth and dropped into it. The lead is now totally immersed in the water. The tube is shaken to remove air-bubbles from the surface of the lead and allowed to stand in a cupboard for one, three, seven, or fourteen days.

"(*a*) *If there is no evidence of erosion*, the water is decanted into a 50 c.c. Nessler cylinder and the lead strip shaken with about 10 c.c. of distilled water, which is poured into the cylinder. The lead is then removed and the tube washed with 5 c.c. of dilute acetic acid (roughly decinormal) and with water until there is 50 c.c. in the cylinder.

"(*b*) *If erosion is doubtful*, the water is decanted into a 50 c.c. Nessler cylinder, the lead dropped into a funnel, and any eroded lead washed off with a jet of water into the cylinder. Dilute acetic acid is used as before.

"(*c*) *If there is evident erosion*, the turbid water is decanted into a 100 c.c. flask. The lead is shaken out into a funnel and washed with a jet of distilled water. Ten cubic centimeters of the dilute acetic acid is put into the tube and allowed to stand a short time before it is emptied into the flask. The tube is washed with more distilled water and the flask filled up to the mark. When the solution is quite clear, 50 c.c. or a smaller measured quantity is put into a Nessler cylinder and made up to 50 c.c.

"Comparison is made in 50 c.c. cylinders. Five cubic centimeters of the dilute acetic acid (or a quantity sufficient to make the amount present up to 5 c.c.) and 3 c.c. of saturated hydrogen sulphide solution are added to every cylinder. The color produced by the colloidal lead sulphide is matched by standards prepared at the same time. The standards are made with distilled water, except in the case of very dark waters, when it is advisable to include 10 c.c of the original water.

"The standard lead solution used is of such a strength that 1 c.c. = 0.0001 grm. Pb, and is prepared from a solution a hundred times its strength, which contains 1.831 grm. of lead acetate and 10 c.c. of N/1 acetic acid per 100 c.c. Standards may be increased by 0.1 or 0.2 c.c. of the lead solution after the hydrogen sulphide has been added, but these standards are not so reliable as those to which the hydrogen sulphide is added last."

* The peat extract was not fresh. For effect of fresh extract see following table.

TABLE SHOWING ACTIONS OF VARIOUS WATERS ON LEAD.
(Houston's Method.)

Source of Sample.	Reaction to Lacmoid.	Alkalinity. P.P.M.	Hardness. P.P.M.	Lead Found in Water. P P.M.	Remarks.
Distilled water (laboratory)	Slightly acid	0	0	420	Erosion.
Well	Slightly acid	28.5	31.6	131	No erosion.
Well	Slightly acid	29.1	44.6	18	
Well, Chatham, Mass.	Slightly acid	24.1	38.0	26	No erosion.
Well, Harvard, Mass.	Slightly acid	13.9	35.4	18	
Well, Camden, N. J.	Slightly acid	137.5	220.	8	Free CO_2, 191 p.p.m.
Well, aërated and filtered	Neutral	132.	210.	6	
Well, Hamilton, Mass.	Neutral	22.1	27.8	3	
Well, Newport, R. I.	Neutral	88.7	22.1	4	
Well, Plainfield, N. J.	Alkaline	50.4	57.2	11	
Spring, Waterbury, Conn.	Slightly acid	23.7	75.4	24	
Charles River, Milford	Slightly acid	7.9	11.1	32	
Milford Tap	Neutral	24.0	28.6	7	
Reservoir, Exeter, N. H.	Alkaline	24.1	27.0	6	
Reservoir, Exeter, N. H., filtered	Slightly acid	11.2	27.4	11	Mechanical filter effluent.
Reservoir, Mt. Holyoke College	Slightly acid	27.2	39.0	20	
Reservoir, Mt. Holyoke College, filtered	Slightly acid	14.1	39.0	29	Mechanical filter effluent.
Tap, Stroudsburg, Pa.	Neutral	22.1	24.8	5	
McMichael's Creek, Pa.	Acid	14.6	20.5	3	Turbid water.
Peat extract in distilled water	Acid	....	....	550	Color, 25 p.p.m.
Peat extract in distilled water	Acid	....	....	700	Color, 50 p.p.m.
Peat extract in distilled water	Acid	....	....	900	Color, 100 p.p.m.
Peat extract in distilled water	Acid	....	....	1 110	Color, 150 p.p.m.
Peat extract in Boston tap water	Acid	....	....	90	Color, 25 p.p.m.
Peat extract in Boston tap water	Acid	....	....	160	Color, 50 p.p.m.
Peat extract in Boston tap water	Acid	....	....	170	Color, 100 p.p.m.
Peat extract in Boston tap water	Acid	....	....	210	Color, 150 p.p.m.
Boston tap water	Alkaline	12.1	19.2	113	Erosion.

Prevention of Action.

The action of water on lead is prevented in many cases by the formation of a protective coating of basic lead carbonate, of silica, of organic matter, or of other substances deposited from the water. This coating adheres closely to the exposed surface of the pipe and practically prevents action. Nearly all waters may be made to form protective coatings by the addition of certain chemicals to them.

Natural Protection.

The formation of a protective coating is best illustrated by the following experiment:

A test piece of lead was placed successively in 10 c.c. portions of Boston tap water, and in each case allowed to stand seven days before changing the water. The water was changed twice, and the lead determined in each successive portion with the following results:

Experiment to Demonstrate the Formation of Protective Coating.

Test No.	Age of Surface, Days.	Lead Eroded, P.P.M.
1	7	110
2	14	42
3	21	26

Prof. William P. Mason* found the following amounts of metal in city rain water which had been stored three and a half months in contact with old and new lead surfaces, respectively:

Old lead	3.65 p.p.m.
New lead	58.10 p.p.m.

The experiments demonstrate why old lead surfaces may be used for conveying certain waters which actively attack clean, new pipe.

Fig. 3 shows the coating formed on the lead services at Concord, Mass., from a pond water; also shows a specimen of the Concord pipe after the coating has dried. Fig. 2 shows a specimen of service pipe, recently removed from the Boston works. (Fig. 3.)

Certain waters which contain no organic matter also form protective coatings on lead. These waters are either alkaline, or deposit carbonates, sulphates, silica, or silicates on the surface of the lead. Basic carbonate of lead deposits from certain waters, and is a great protection. Its solubility† is equivalent to 1.3 parts of lead per million of pure water.

Artificial Protection.

Dr. Houston (*loc. cit.*) showed that the addition of small amounts of sodium carbonate prevented the action due to peaty waters, and that

* Water Supply, p. 461.

† Pleissner (1907).

only small amounts of this chemical were required to coat the metal with an adherent film. Calcium carbonate and bicarbonate also inhibit erosion, but relatively large amounts of lime (calcium hydrate) are required to produce equivalent results.

Liverseege and Knapp (*loc. cit.*) have made careful experiments to determine the best chemicals to prevent erosion of lead by the Caban Reservoir water (Elan Valley, Wales). This water is alkaline to lacmoid,

FIG. 3. SHOWING COATINGS ON CONCORD (MASS.) SERVICE PIPE.

and has an alkalinity of only 3 p.p.m. Its action on lead, therefore, is not due to peaty acids. Calcium carbonate (chalk) is the chemical added. The results of their experiments are given in Fig. 4.

They also found that as little as five parts of potassium permanganate per million were sufficient to form a protective coating and prevent erosion.

The practice of adding calcium carbonate in the form of powdered chalk to very soft peaty waters has been common in England for very many years, and the results have been satisfactory. Descriptions of this process as applied in practice have been given by Houston (*loc. cit.*), Marsh,* McCauley,† and others. Among the important cities where the treatment is applied are Sheffield, Wakefield, and Bradford, England. Prof. George C. Whipple‡ and others have discussed before this Association the removal of the corrosive properties of water by "decarbonation," or, to use the term which the writer prefers, by "neutralization."

While this paper has to do with the practice rather than the theory of prevention, it may be stated in brief that prevention of corrosion consists in neutralizing the acid components of the water by the addition of

* Notes on the Sheffield Water Supply. L. S. M. Marsh, Proc. Inst. C. E., Vol. *CLXXXI*, Session 1909–1910.

† Same Journal, *CLXXXI*, 8.

‡ JOURNAL, *XXVII*, 193 and 445. "Decarbonation as a means of removing the corrosive properties of public water supplies."

certain alkalies, or, to state the problem in scientific terms, to neutralize the effect of the hydrogen (H) ions by the introduction of hydroxyl (OH), carbonate (CO_3), or bicarbonate (HCO_3) ions.

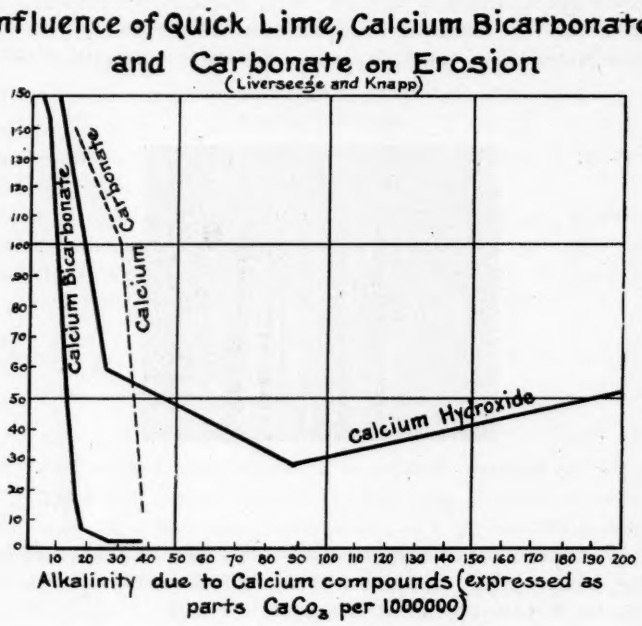
Influence of Quick Lime, Calcium Bicarbonate and Carbonate on Erosion
(Liverseege and Knapp)
Calcium Bicarbonate
Calcium Carbonate
Calcium Hydroxide
Alkalinity due to Calcium compounds (expressed as parts CaCo3 per 1000000)

FIG. 4.

This theory reduces itself in practice to the following:

Kind of Water.	Best Chemical for Treatment.
Surface waters which are acid to lacmoid, are soft and contain oxygen	Chalk ($CaCO_3$)
Surface waters which are soft and contain both oxygen and high carbon dioxide	Lime (CaO)
Ground waters of low alkalinity, containing relatively small amounts of carbon dioxide	Chalk or lime
Ground waters of high alkalinity, containing large amounts of carbon dioxide	Lime

Waters containing large amounts of carbon dioxide and of high alkalinity are improved by aëration, while the reverse is true when the waters are of low alkalinity and soft.*

* See page 247.

Experiences at Milford and Hopedale.

The first water supply of Milford, Mass., and the adjoining town of Hopedale was taken from three wells along the bank of the Charles River at a point just above Milford. Most of the services in the original works, built in 1881, were of lead. As cited above, alleged cases of lead poisoning occurred during the early years of operation, with the result that in 1903 the company built slow sand filters, and thereafter the consumers were largely supplied with filtered water from the Charles River, in place of water from the wells. Following the placing of the filters in service, the cases of lead poisoning disappeared, and until 1914 the company believed that it had done everything necessary to protect its consumers. In that year, however, one suspicious case of illness occurred, and while the patient was unusually sensitive, the water used was drawn through the long service pipe supplying the patient's house. An examination of the filter and its product indicated that between January, 1904, and June, 1914, when the tests were made, a large amount of organic matter derived from the colored Charles River water had been gradually stored in the sand. This was demonstrated by analyses of samples of sand collected from the surface and from a point six inches below the surface of the filter. The results of analysis were as follows:

Point of Sampling.	Loss on Ignition.	Albuminoid Ammonia.
Surface	0.58 per cent.	81 p.p.m.
6 in. below surface	0.51 per cent.	63 p.p.m.

The organic matter fermented and produced carbon dioxide. This was shown by twenty-four-hourly determinations of carbon dioxide and oxygen, in the influent and effluent of the Milford Water Company's filter. The results were as follows:

	Parts per Million.					
	Carbon Dioxide.			Dissolved Oxygen.		
Source of Sample.	Av.	Max.	Min.	Av.	Max.	Min.
Charles River	7.15	8.5	6.2	8.32	8.73	7.89
Filter effluent	15.1	16.8	13.5	5.77	6.49	5.02

It was therefore concluded that the causes of the corrosion of the service pipes were an excessive amount of carbon dioxide, the presence of oxygen, also low hardness and alkalinity. The average results of chemical analyses of the water are appended.

Experiments were begun immediately to determine what chemicals would be most effective to counteract the erosive action of the water.

Experiments.

Experiments were made by exposing 8-in. pieces of $\frac{1}{2}$-in. lead pipe, all from the same coil, each piece of the same weight, to samples of Milford water before and after aëration, and with and without the addition of certain protective chemicals. For a control, the action of Milford water was

compared with that of Boston Metropolitan water drawn from the tap in the writer's laboratory. Experiments were conducted in sealed bottles and under conditions uniform for all samples tested. The results are given in the following table:

RESULTS OF EXPERIMENTS TO DETERMINE THE AMOUNT AND KIND OF CHEMICAL NECESSARY TO ADD TO MILFORD WATER TO PREVENT ITS CORROSIVE ACTION UPON LEAD PIPE.

Number and Description.	Lead Dissolved in Six Days. Parts per Million.	
	First Experiment, June 11.	Second Experiment, June 30.
1. Milford water	27.0	9.5
2. Milford water, aërated	84.0	54.5
3. Metropolitan water	108.0	129.0
4. Milford water plus 15 p.p.m. chalk	10.0	14.0
5. Milford water aërated, then 15 p.p.m. chalk added	16.0	13.0
6. Milford water plus 15 p.p.m. chalk, then aërated,	12.0	17.0
7. Milford water plus 15 p.p.m. magnesia, then aërated	10.0	....
8. Milford water aërated, then 8.5 p.p.m. quick lime added	....	22.5
9. Milford water plus 8.5 p.p.m. quick lime	....	1.1
10. Milford water plus 12 p.p.m. quick lime, then aërated	....	1.4
11. Milford water plus 20 p.p.m. quick lime, then aërated	....	1.35

The characteristics of the waters used for the experiments are shown in the following table:

CHARACTERISTICS OF SAMPLES TESTED.

	Parts per Million.	
	First Experiment.	Second Experiment.
Carbon dioxide, Milford water	9.8	11.3
Alkalinity, Milford water	7.1	7.0
Hardness, Milford water	11.9	11.9
Total solids, Milford water	38.0	39.0
Carbon dioxide, Milford water after aëration	5.2	4.2
Carbon dioxide, Metropolitan water	3.1	2.9
Alkalinity, Metropolitan water	8.5	8.4
Hardness, Metropolitan water	18.5	18.5
Total solids, Metropolitan water	39.0	40.0

The dissolved oxygen was not determined, as all samples were unavoidably exposed to the air in the laboratory.

The above results were remarkable and somewhat surprising, and from them it was concluded:

1. The aëration of the Milford water is a decided disadvantage, as may be seen by comparing tests Nos. 2 and 8 with Nos. 1 and 9. The reason for this increased action is that the oxygen precipitates the lead previously dissolved by the carbon dioxide, thereby setting free an equiva-

lent amount of carbon dioxide to re-attack the lead pipe, and so on until not only is the carbon dioxide used up, but the oxygen as well. In other words, the plumbo-solvent action of this water can be measured, not only by the amount of carbon dioxide, but also by the amount of oxygen, and at present it combines the disadvantages of a ground water containing carbon dioxide with those of a filtered surface water containing oxygen as well as carbon dioxide.

2. The addition of 15 parts of chalk or magnesia per million of the water greatly reduces the solvent action of the water. The reduction is less when the water is aërated.

3. The addition of 8.5 parts of quick lime, which is equivalent to 15 parts of chalk, reduces the action of the unaërated water on lead to practically nothing, only 1.1 parts of lead being dissolved after six days' contact. The reason for the increased action of the lime as compared with chalk is that the lime combines directly with the carbon dioxide, thereby taking it out of action.

4. By increasing the amount of lime, the corrosive action of the water can be prevented, even though aërated.

As a result of the experiments, the writer recommended that the water be treated with from 8 to 10 parts of quicklime per million, equivalent to from 85 to 100 lb. of high-grade commercial lime per million gallons.

The recommendation was adopted by the company. In 1914 the neutralizing plant was built, and in December of that year put into service. The plant consisted of the following parts:

1. Storehouse for lime.
2. Tanks for making milk-of-lime.
3. Pumps for circulating the milk-of-lime through the apparatus for regulating the application of lime.
4. Feed regulator.
5. Tank for separating the lime from the sand and other insoluble matter.
6. Feed box with ball cock to prevent the entrance of air into the suction with the lime water.
7. Pitot tubes and manometers for measuring the rate of flow through the pumps.
8. Meters for measuring the water used to dissolve the lime and drive the Pelton wheel.
9. Pelton wheel to drive mixers and pump; water to be returned to well. This was by far the cheapest source of power.
10. Shafting, piping, belting, scales, wheelbarrow, etc.
11. House for apparatus.

The arrangement of the plant is shown in Fig. 5.

These devices were installed and the plant placed in operation in

December, 1914. The good results of treatment were apparent at once. A laboratory test, employing the method used in the writer's previous experiments,* gave the following results:

Source of Sample.	Lead Dissolved from Service. P.P.M.
Filter effluent untreated	5.8
Filter effluent lime-treated	1.55

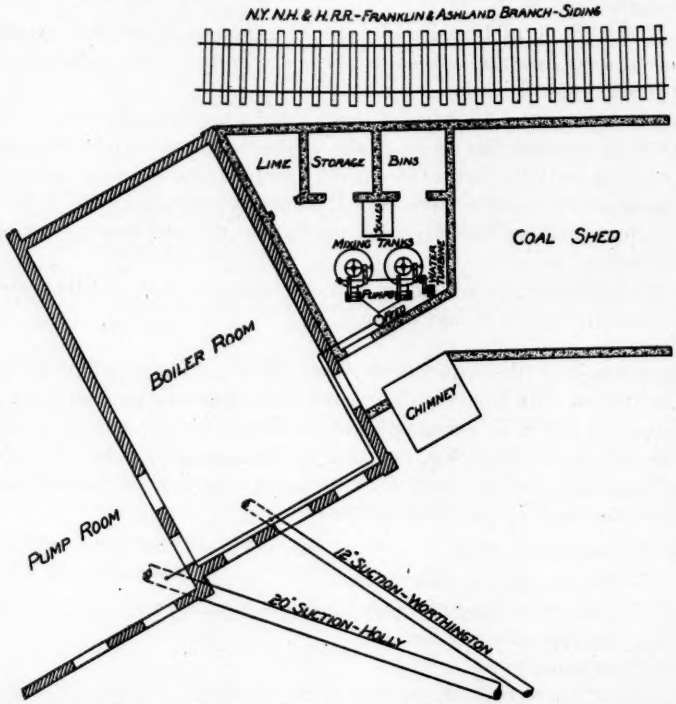

FIG. 5. PLAN OF NEUTRALIZING PLANT OF MILFORD WATER COMPANY.

On December 14, determinations of the dissolved oxygen and carbon dioxide in samples taken from various points in the system gave the results shown in the following table:

RESULTS OF GAS DETERMINATIONS AT MILFORD.
December 14, 1914.

Source of Sample.	Parts per Million. Dissolved Oxygen.	Carbon Dioxide.
Charles River water	9.23	2.4
Filter effluent	8.35	7.6
Well No. 2	2.94	17.4
Well No. 3	6.43	12.8
Lime-treated water in pumping station	11.82	0.0
Lime-treated water from tap, 16 West Pine Street,	11.92	0.0

* See page 252.

Tests for the presence of lead in the treated water, from a tap in the city under conditions of ordinary use, and after standing in the service over night, respectively, are given in the following table, in which are also given the results of similar tests of samples collected on September 21, before the plant was put in operation.

	Lead, Parts per Million.	
Date, 1914.	Ordinary Use.	After Standing in Service Overnight.
September 21	0.27	2.63
December 14	0.063	0.183

The above indicates a reduction of 79 per cent. in the erosive action of the water under conditions of ordinary use, and of 93 per cent. after standing in the service pipe overnight. Later results show even higher reductions.

Results in Practice.

Since December, 1914, monthly samples have been collected from a tap under conditions of ordinary use and after standing overnight in the lead service, respectively. The annual average results under conditions of ordinary use are as follows:

ANNUAL AVERAGE RESULTS OF ANALYSES.
(Parts per Million.)

		Free Carbon	Lead.			Average Lime
Year.	Hardness.	Dioxide.	Average.	Maximum.	Minimum.	Added.
1914	13.0	18.6	0.27	2.63	...	0.0
1915	30.0	0.30	0.124	0.15	0.12	12.9
1916	24.0	0.25	0.10	0.11	0.10	12.1
1917	34.9	0.40	0.09	0.10	0.08	11.4
1918	31.8	0.23	0.082	0.11	0.07	11.1
1919	36.7	1.40	0.085	0.10	0.07	10.0

It will be noted that the action of the water on the lead decreased from 1915 to 1918. It was slightly higher in 1919, due to the fact that the dose of lime was purposely decreased, as was indicated by the increase in free carbon dioxide. On an average, the Milford-Hopedale water requires a dose of about 11 parts of commercial quicklime per million, equivalent to less than 10 parts of calcium oxide (CaO).

At the present time the plant is being operated so as to keep below 0.1 p.p.m. the amount of lead found in the water under conditions of ordinary use.

The following diagram (Fig. 6) illustrates the differences between the average amounts of lead found in the water under conditions of ordinary use and after standing in the service pipe overnight, respectively.

Protection by Filtration.

Schmidt* showed that lead compounds are found in certain waters in a state of true or colloidal suspension, and may be removed therefrom by Berkefeld or similar filters. Following that suggestion, Schwenkenbecher

* Archiv. f. Hygiene, 1913, *80*, 70.

and Neisser* experimented with these filters attached to lead services, and were able to reduce the amount of lead in the water so supplied from as low as 0.7 and as high as 6.0 p.p.m. to 0.0, and to stop cases of poisoning caused by the unfiltered water.

These experiments have been repeated under the writer's direction, using a water supplied through a lead service, and employing two filters: one, a "Berkefeld" filter containing a tube formed of baked infusorial

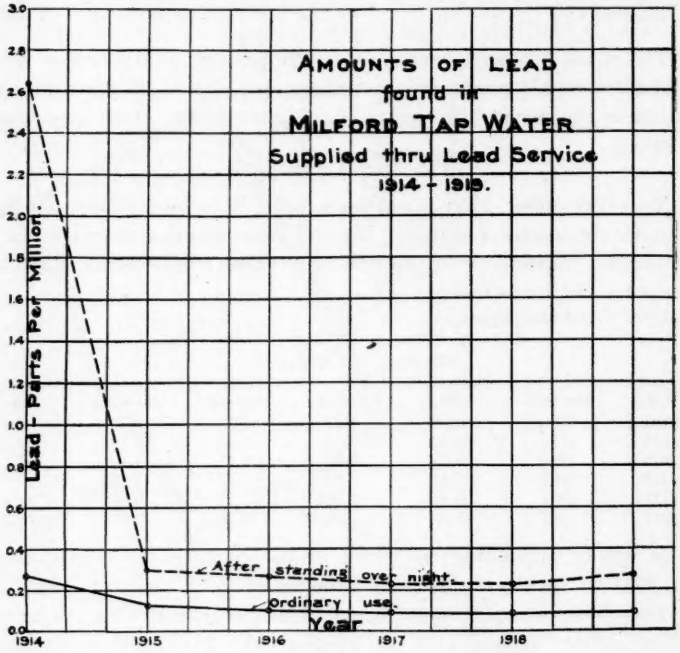

FIG. 6.

earth; and the other, a "Boston" filter containing tubes of unglazed porcelain. During four months of operation, samples were collected from each of these filters with the following results:

RESULTS OF EXPERIMENTS WITH HOUSEHOLD TUBE FILTERS.
(Parts per Million.)

Date.	Unfiltered. Standing Overnight.	Unfiltered, Ordinary Use.	Berkefeld Filter Effluent.	Boston Filter Effluent.
January, 1920.....	0.28	0.08	....	0.06
February, 1920.....	0.30	0.09	0.05	....
March, 1920.....	0.28	0.09	....	0.07
April, 1920.....	0.29	0.08	0.05	....
Mean.....	0.29	0.085	0.05	0.065

* Munchener Med. Wochensch., 1914, *61*, 352; Gesundheitsingenieur, 1913, No. 51.

These experiments show that household filters may be depended upon to remove from the water those compounds of lead which are dislodged from the service pipe during periods of standing and are present in the water first drawn; these are, of course, the most dangerous. They do not greatly reduce the amounts of lead found in water drawn under conditions of ordinary use, and seem hardly worth while where care is taken to empty the service pipe before using the water for drinking. They are an offset to carelessness, and as such are sometimes advisable, although they are usually ill-cared for and become brood chambers for bacteria.

The Toxic Action of Lead in Water.

Lead is a cumulative poison. Its usual and well-known manifestations are anemia, cachexia, blue line around the gums, colic, wrist-drop, contracted kidney, etc. It is possible, however, to have evidences of absorption of lead without the usual symptoms of lead poisoning. These may consist of the presence of lead in the urine (especially after the administration of potassium iodide), blood changes, and the tendency of women to have miscarriages.

Prof. Reid Hunt, of the Department of Pharmacology of the Harvard University Medical School, has been consulted, and has reported cases in which a considerable number of persons were poisoned by drinking water containing the following amounts of lead:

Lead, P.P.M.	Place.
0.5 — 1.6	At Sprokhoevel (in Westphalia), (Lemmer).
0.7 — 12.5	At a village in the Taunus (Schwenkenbecher and Neisser).
0.998 — 9.983	At Sheffield (White and Allen).
1.997	At Huddersfield (Aird).
1.143 — 11.98	At Huddersfield (Stevenson).
1.43 — 4.28	At Manchester (Calvert).
2.00 — 15.00	At Castle Claremont (de Mussy).
8.7	At Keighley (Stevenson).

Amounts which a number of writers have stated to be poisonous or tolerated are as follows:

Lead, P.P.M.	
0.36	*may* be poisonous (A. Smith).
1.41	may not be poisonous (A. Smith).
0.36	maximum permissible amount (Rubner).
0.3	or, at most, 0.5 permissible (Schwenkenbecher and Neisser).
0.7	maximum permissible amount (Steiner).
0.71	tolerated (J. Smith).
1.00	tolerated (Gärtner) (Telekey).
1.43	tolerated (?) (White).

At Dessau there were many cases of poisoning when the water contained 4.14 p.p.m. The lead was reduced to 0–0.5 p.p.m. and no case of poisoning was reported during the following ten years. On the other hand, certain French hygienists have reported isolated cases of poisoning from

0.1 p.p.m., and it is stated that soda water containing 0.32 p.p.m. has caused poisoning, and 0.8 p.p.m., death.

Thresh, "Examination of Water," states that he has noted cases of lead poisoning with waters varying from 0.14 to 1.4 parts of lead per million.

It would seem from the above that water containing less than 0.1 part of lead per million would, when judged by practical standards, be considered safe, and the recent experience at Milford supports this opinion.

It is apparent that there is no proof that drinking waters containing 0.1 part of lead per million, or even more, cause disease. This lack of proof may be due to imperfect methods of medical diagnosis.

Practical Considerations.

It is obvious, of course, that the action on lead of any water under consideration as a new source of supply should be known before the metal for services is chosen. Managers of works already in operation with lead services should certainly inform themselves regarding their own conditions, and if their water be found to attack lead to any appreciable degree, they should take steps to prevent or minimize its effect.

Waters which attack lead will usually attack iron, — both plain and galvanized, — also steel. Consequently, the action of such may be prevented best by the use of cement-lined services. Many water works, however, have thousands of dollars invested in lead services. If the water supplying such works be found to attack lead services, the best plan is to replace them gradually, using cement-lined iron pipe, meanwhile protecting consumers by the proper treatment of the water supplied through the existing lead services. This course has been followed by the Milford Water Company with gratifying results.

Acknowledgments.

The writer wishes to thank the Engineering Department of the State Department of Health for analytical data; Messrs. McInnes and Robinson for specimens of pipe; Mr. A. L. Gammage, of Weston & Sampson's laboratory, who has made most of the determinations of lead; and especially Mr. Frank J. Dutcher, treasurer, and Mr. J. W. Kay, superintendent, of the Milford Water Company, for their broad-minded and full coöperation during several interesting years.

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Harrington, "Practical Hygiene," 344 *et seq.*

MILFORD-HOPEDALE SUPPLY.*

Average Results of Analyses.
(Parts in 1 000 000.)

Source.	Date.	Color.	Oxygen Consumed.	Nitrogen as				Chlorine.	Hardness by Soap.	Alkalinity.	Residue on Evaporation. Total.	Iron.	Free Carbon Dioxide.	Lead, Ordinary Use.		
				Free Ammonia.	Albuminoid Ammonia. Total.	Nitrates.	Nitrates.							Av.	Max.	Min.
Wells	1887–02	12.5	1.95	.007	.076	.0005	.223	2.67	12.66	...	39.80	.131	...	...	...	...
Tap	1888–03	6.4	2.70	.002	.045	.00075	.191	2.80	10.66	...	33.52	.153	...	1.39	9.40	0.167
Charles River	1887–00	64.3	6.69	.015	.218	.0000	.091	2.50	5.00	...	34.00	...	...	...	...	...
Charles River†	1905–14	19.8	2.75	.0116	.147	.0001	.121	3.46	11.33	...	38.22	.138	18.6	0.27	2.63	...
Charles River‡	1915	28.0	2.5	.013	.087	.0000	.064	3.80	30.00	25.0	65.60	.210	0.0	0.12	0.15	0.12
Charles River	1916	23.0	...	.007	.062	.0000	...	3.60	24.00	29.6	55.70	.180	0.25	0.10	0.11	0.10
Charles River	1917	20.0	...	.025	.089	...	...	4.00	34.90	29.4	53.30	.24	0.40	0.09	0.10	0.08
Charles River	1918	20.0	...	.011	.069	...	...	3.70	31.80	27.9	63.70	.27	0.23	0.08	0.11	0.07
Charles River	1919	22.0	...	.008	.072	...	...	3.40	24.00	27.5	...	.31	1.40	0.09	0.10	0.07

* By Mass. State Department of Health and Weston & Sampson.
†Taken from tap after being filtered.
‡Filtered and treated.

Discussion.

Charles D. Howard.* In New Hampshire, we have for many years been fighting the lead pipe proposition. The attitude of our Board is that lead and its salts are definitely recognized as active poisons, and that the use of this material as a water conductor is to be deemed as unsafe and therefore as something to be uniformly avoided.

For some years practically no private installations using lead pipe have been made, while, as for the public water systems, any plans or specifications calling for this variety of pipe would fail to receive the approval of our board as required by law.

With all samples, representing both public and private sources, wherever there is a record of lead pipe in use, it is our practice to quantitatively estimate the proportion of lead present. Formerly up to 0.05 parts per hundred thousand was regarded as "safe." At present we find this "safe" limit lowered to 0.025 parts. As a matter of fact, I do not believe we are justified in considering any determinable amount of lead as "safe" under any and all circumstances. It is not alone that the susceptibility of the individual differs, but also that the amount of this metal, as occurring in the dissolved or suspended condition in water will vary, being governed by a variety of changing conditions.

It is realized that the expense of replacing a lead system already existent would be very material, and for this reason there is, undoubtedly, justification for adopting the alternative plan of chemical treatment. I further realize that there are lead pipe systems in use which apparently are not or never have given trouble. Nevertheless, the water-works manager who, in the light of present-day knowledge of the subject, deliberately installs a pipe system of this variety, is doing a most unwise thing.

Stephen DeM. Gage.† I have listened with much pleasure to Mr. Weston's excellent paper, because it deals with one phase of the public water-supply problem in which I have been especially interested for some time.

Mr. Weston has mentioned the 1898 report of the Massachusetts State Board of Health on Lead Poisoning and the studies of Mr. Clark on the action of water on lead published in that report. In some manner a great many people have obtained the impression that these Massachusetts reports are authority for the assumption that surface waters do not attack lead, and that unless there is at least one-half part of lead per million in a water it is not likely to be dangerous to health. This is entirely a misconception, and I am glad to have the opportunity to correct it. In the general report of the Massachusetts Board for 1898 it is stated:

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* Chemist, New Hampshire State Board of Health.

† Chemist and Sanitary Engineer, State Board of Health of Rhode Island.

" The exact amount of lead which may be taken into the system without producing harm is not definitely known and may vary with different people, but it is known that the continuous use of water containing quantities of lead as small as .05 part per 100 000 has caused serious injury to health."

On page 569 of the same report Mr. Clark says:

" Interviews with physicians in the cities and towns where series of samples were taken fail to show a prevalence of lead poisoning in any except the four places mentioned above, although occasional cases have been noted in several other towns that have ground-water supplies. Our investigations so far made in the towns and cities having surface-water supplies have failed to reveal any cases whatever, although many of these waters attack lead, and the lead taken in this manner into the systems of many of the inhabitants may cause mild or unrecognized cases of lead poisoning."

These are clear statements of the belief existing at that time that very small amounts of lead might be harmful to some people, that there might be unrecognized cases of mild lead poisoning, and that surface waters would absorb lead in greater or less degree.

During the past few years more attention has been paid to obscure causes of minor ailments, and incidentally much has been learned about lead poisoning.

While we are in the same position to-day as we were twenty years ago as regards definite knowledge as to the exact amount of lead which may be taken into the system without producing harm, we do know definitely that some people are so sensitive that they are unfavorably affected by the presence of very minute quantities of lead in their food or drinking water.

It was my good fortune to be associated with Mr. Clark at the time these investigations were in progress and for some years afterward, and while our time was largely taken up with more urgent problems, every once in a while the thought would come that there was a whole lot we didn't know about lead poisoning. When I went to Rhode Island in 1914 I found that not only was the use of lead for services almost universal, but a very large proportion of the houses were piped with lead. I looked up the mortality records and questioned a good many physicians, and, so far as I could learn, lead poisoning — that is to say, chronic lead poisoning — was practically unknown in the state.

In 1915, or early in 1916, my interest in the subject was again aroused by two instances of lead poisoning which had gone unrecognized for some time. One of these was the case of a middle-aged physician who had retired from active practice because of ill-health of both himself and his wife. In some manner he was led to suspect his water supply and asked us for assistance. On investigation we found that he was using water from an excellent spring brought into the house through lead pipe. Analysis of the water showed lead present in small amounts, about .2 part per mil-

lion, as I remember it. We advised him that while this amount of lead was not usually considered dangerous, it was quite possible that he might have an idiocyncrasy for lead, and that it would do no harm if he changed his drinking water to one which could not possibly have any lead. This he did and in a few months both he and his wife regained their health and he was able to resume practice. He later wrote us a letter of appreciation in which he stated that both he and his wife had believed that they were doomed to a premature old age until we had shown them the path back to health.

Another and even more illuminating instance is that of a small isolated community of eight or ten families. If I remember correctly, all but one of these families obtained their water through lead pipe from springs on the side of a hill. Practically every member of these families was afflicted with what they called rheumatism, one old couple being practically bed-ridden. One house was so situated that the spring supply was not available, and this family obtained their drinking water from a well with a bucket and chain. This family were free from rheumatism. One doctor after another had been called to treat the rheumatic sufferers without avail. Finally a physician was called who had heard about the previous case, and as a last resort asked us to look into the lead question. Our investigations showed considerable amounts of lead present in the water as delivered at each of these houses, and upon our advice the lead pipe was removed and other material substituted. In the course of a few months rheumatism practically disappeared from that community.

Since then I have talked lead poisoning to physicians and waterworks officials in our state until some of the latter undoubtedly think I am a crank on the subject. We have not had the time or the funds to make a thorough lead survey of all our water supplies. In fact, unless such a survey was exhaustive, it might show very misleading results, for the reason that, in our experience, lead solvency may vary widely in two adjacent services on the same water supply. We are, however, getting at the facts in another way by helping the physicians to detect the mild cases and thus build up a record of their prevalence. In Rhode Island we do something which I think is not done by any other state in the Union, that is, we make any kind of a test or analysis which will help a physician to form a correct diagnosis of any disease. A good many of the doctors have formed the habit of coming in to talk over their doubtful cases and see if there isn't something we can do to help them find out what is the source of the ailment. Oftentimes one or more of the symptoms is suspicious, and we suggest comparative tests for lead on the urine and on the drinking water. In this way we find now a case here, now one there. Hardly a month goes by but we make one or two additions to the list. Obscure cases, indigestion, chronic constipation, kidney trouble, rheumatism, and other ailments which do not yield to treatment may be only lead poisoning masquerading under one of its many aliases.

The more I study the subject the more convinced I am that lead poisoning is a contributory cause of more or less sickness in practically every community where lead is used for conveying drinking water. If this be true, then a good many of our public water-supply officials will have to face a big problem. Treatment of the water will undoubtedly greatly reduce its plumbo-solvent action and thus lower the incidence of lead poisoning, but it is extremely doubtful if any treatment can be made so thoroughly efficient that it will eliminate all chance of the water containing lead some of the time. It begins to look very much as though the day of the lead pipe for water-supply purposes was doomed, and that eventually the lead services already in would have to be replaced by some other material. Certainly no water-works official would care to take the responsibility of continuing to use lead with the chance that it might seriously affect the health of even a small proportion of his consumers.

MR. A. O. DOANE.* I should like to inquire whether anybody has made any experiments or has any data about the effects of lead in paints upon water tanks. We have made some studies that showed that when red-lead paint was used, — in tank experiments where the proportion of painted surface to volume of water was very much more, probably eight or ten times as much as in the standpipe, — the lead found in the water was not above the safe limit. We made the experiments by painting plates of steel with the same lead pigment that we intended to use in the standpipe. We put them in a crock, and allowed them to stand under water for some weeks. The water in the crock was then examined by the State Board of Health and they gave us a clean bill of health on it, reporting that the water did not take up, even in the concentrated form, a dangerous amount of lead — I think it was less than eight-tenths in a million.

MR. WESTON. I am familiar with this subject, but have never seen a case of poisoning by red lead. In the first place, red-lead pigment is mechanically mixed with linseed oil, which makes an envelope around the pigment; and then there is a coating, on top of that, of various substances out of the water; so you would take no chances of injury from this source.

MR. DOANE. It does not seem to make any trouble, and in my opinion red-lead pigments are the best things to resist water, so that it is quite an important point in the painting of standpipes.

* Division Engineer, Metropolitan Water Board, Boston, Mass.

THE RELATION BETWEEN OFFICE METHODS, REGULATIONS, AND THE WATER CONSUMER.

REEVES J. NEWSOM.*

[*September 9, 1920.*]

Water consumers, as a class, are peaceful, law abiding, and willing enough to comply with the rules of the department when informed of their existence, but there is always in every community a certain small percentage who keep the water-works officials on the jump, and because of whom it becomes necessary to bind all consumers to a contract and with regulations which are as near air-tight as it is possible to make them.

These consumers are mainly of three kinds, — the one who feels that because he pays taxes or is a life-long resident he should get his water service free; the one who has some brilliant idea of how his case can be handled so that it will be a few dollars less expensive, irrespective of the precedents or standards which he would upset; and the all-around trouble maker who will not sign a contract or pay a bill until he is forced to, who threatens all sorts of dire things if his water is shut off, and who is continually looking for an opportunity to collect for damages of some kind from failure in some feature of the service.

The new consumer, when he applies for water in Lynn, is presented with a card form of contract which he is required to sign, and when he does so he has practically forfeited all his rights, as the contract contains these stipulations:

"In consideration of the supplying of said water, said owner hereby agrees to pay for the same in accordance with such rates as are from time to time established, and this agreement to pay shall remain in force and be binding upon him so long as the city of Lynn shall continue to supply water to the said premises, unless he shall have notified the said City in writing that he no longer desires the water service and shall have stated in said notice the name of the new consumer. He agrees to be bound by the rules and regulations of the Water Department and all subsequent changes therein, and to pay all charges for excess piping or special construction as prescribed in those rules and regulations. It is understood and agreed that the City of Lynn does not guarantee to furnish constant pressure nor uninterrupted service."

If a new owner of property fails to make application for water, he receives in due course of time a notice of the following tenure:

"It has been reported to this department that you are the owner of the property at blank street. If such is the case, this is to notify you

* Commissioner of Water Supply, Lynn, Mass.

that under the regulations of this department, you, as the new owner of this property, have no right to the use of water service unless you have made a written application for water on the prescribed form in this office. You are requested to call at the water office, City Hall, within one week and make such application."

Failure to comply with this request is followed up promptly by shutting off the water.

It is necessary to have a contract with the current owner of all property, and to prevent the use of an excessive number of contract cards, each one is provided on the back with space for six transfers of property, the new owner signing this statement:

"In consideration of the continuation of service, I hereby agree to be bound by the provisions of the contract on the reverse side of this card, from blank date, as though I were, in fact, the original applicant."

All applicants for water do not submit just the simple request for a single service, but occasionally an unusual and out-of-the-ordinary use for water is contemplated, or a building is so long that the consumer desires the City to go to the expense of putting in two services instead of his putting long feeder lines in the basement. Such conditions are covered in the regulations by the following:

"Owners of property desiring any unusual construction, alterations or attachments connected with the water supply must submit plans and specifications for the same to the commissioner for his inspection and approval or disapproval, and his determination as to whether the same are permissible, and the terms and conditions under which their use will be allowed."

"Any consumer requiring, because of special conditions in connection with his use of water, a service pipe between the main and the street line which is larger than one ordinarily needed to furnish the total amount of water which he uses, shall be charged the cost in excess of such a service pipe as is ordinarily furnished, both upon the original installation or a replacement thereof."

"Except by special consent of the commissioner, but one service connection will be made for the same premises, and where standby or emergency services are installed the same shall be metered and the entire expense of installation and maintenance of both service pipe and meter shall be at the expense of the consumer."

The consumer who owns a camp to be occupied only a part of the year, or the lunch-cart owner who wants a well-paved street torn up to give him water, and who may be out of business in six months, are cared for by this regulation:

"Services for other than permanent structures, or which are used only a part of the year, will be put in at the expense of the consumer, the cost to be refunded if the service remains in continuous use for five years."

Two other types of consumers, the one who wants a service in a hurry, irrespective of physical conditions, and the other who wants something other than the standard service in order to get out of it cheaply, are met by these regulations:

"When permission to open a permanently paved street is refused by the Commission on Ways and Drainage, or for any physical reason it is impossible to open a street and the applicant requests that water be furnished temporarily from an adjacent service, the same may be done if considered practicable by the Commissioner of Water Supply, but entirely at the expense of the consumer."

"No new service or main extensions will be granted during December, January, and February, except in such cases as the Commissioner of Water Supply shall deem emergencies."

"Service pipes shall not be placed in the same trench with sewer, gas or electric connections except under special conditions and with the approval of the Commissioner of Water Supply."

Many people apply for water when they are beyond the end of the main or are on a new street. Two methods are provided for such cases, one for the consumer who wants real service, and the other for the one who wants to get off easily:

"Extension of mains (except as hereinafter noted) shall only be made after petition by the real estate owners or their authorized agents, along the line proposed, and upon their entering into an agreement, which shall assure an annual revenue to the Department equal to 10 per cent. of the cost of laying not exceeding a 6-in. pipe, dating from the time the water is turned into the same for public use."

"When no main pipe is opposite the applicant's premises, the Department will lay at its expense, twenty-five feet (25) of service pipe from the nearest main, but not beyond the street line at the front of the premises. The remainder, if any, must be laid at the applicant's expense."

The contract which the consumer executes covers not only the supplying of water, but a service pipe and a meter installation. The charge for a service pipe is in accordance with the following:

"All service pipes and street boxes will be supplied and put in by the Water Department and will be laid from the street main through the cellar wall or front of building. Service pipes will be laid to the street line without charge, except where ledge work or blasting work, or digging frozen ground is necessary, in which cases the applicant must prepare the trench to the ordinary depth required to insure protection against freezing, or if equipment and labor are available such work may, at the discretion of the Commissioner of Water Supply, be done by the Water Department at the expense of the consumer."

"All pipes laid beyond the street line shall be charged to the consumer whether on a new installation or a replacement, and water will be shut off for non-payment of pipe bills under the same procedure as for non-payment of water bills."

The consumer who may have two or more houses on a service or sprinklers on his lawn, and who would prefer to save the difference between the cost of work done by the City and by plumbers, is taken care of by this provision:

" The Department shall furnish no material for use on private premises, nor do any work thereon, except underground work directly connected with its main pipe system, and then only at the expense of the consumer."

The man who feels that he is better able to judge whether a service pipe should be repaired or renewed than the Water Department is confronted with the following:

" All service pipes between the street line and the cellar wall may be repaired or relayed by the Department when it deems it necessary for the protection of the supply or the giving of satisfactory water service and the cost of the same charged to the consumer."

It was recognized by the writer that it is very essential for the department to have complete control of the meters, but with 5 500 services unmetered, and the hope that they will be metered in the near future, it was desirable to contrive some means of keeping this control without having to furnish the capital for the installation of so many meters. The following paragraphs from the regulations show how the proposition is handled:

" All users of water through metered services shall pay the cost of a proper-sized meter installation, and thereafter the maintenance of the same shall be by the Water Department, which shall include all ordinary repairs and replacements. All repairs of injuries to meters from freezing, hot water, or external causes shall be charged to the consumer. Charges for a new meter installation will, at the discretion of the Commissioner of Water Supply, if requested by the consumer, be levied in equal parts, due and payable with each of the first four quarterly water bills, and all such charges when paid shall be retained by the Water Department and credited to such meter installation and, in the event of failure to make payment of such charges when due, the Water Department shall have the right to shut off the water under the same procedure as for other Water Department charges."

" The proper size of meter required for any given service shall be determined by the Water Department, which shall in all cases furnish the meter to be used, the same to be such type and make as said Water Department shall deem proper."

" All meters shall be set by an employee of the Water Department, and shall not be moved or disturbed except by the same."

" The department shall have the right to remove, repair, or replace any meter at any time it sees fit. All meter installations on services which cannot be shut off for meter repairs shall be equipped with a by-pass at the expense of the consumer."

" If, in the opinion of the commissioner, a meter does not fit the conditions of the service installation, the Department shall have the right to change such meter and charge or refund the difference in value of the meters exchanged."

Under this method of maintenance of meters by the City, we meet with consumers who, due to the rate at which they use water, desire a very large meter, and others who have stumbled on to the brilliant idea of charging their tenants directly for water. We are prepared for them with the following:

"Any consumer requiring, because of special conditions in connection with his use of water, a meter which is larger than one ordinarily needed to register the total amount of water which he uses, or which is of special material or type of construction, shall be charged the cost of the same, and the upkeep of such meter shall be at his expense."

"Where the supply of water through a service is covered by a single meter, the Department will read and maintain but this one meter. If additional or auxiliary meters are wanted for showing subdivisions of such supply, they may be furnished and installed by the Department, at the expense of the consumer, who must assume all responsibility of reading and maintaining the same."

After the consumer has had explained to him the particular regulations which fit his individual case and has signed the contract form, the usual orders are sent from the office for the service pipe and meter installations, and an account is opened on a card form which is filed alphabetically in the proper district.

No new accounts are opened except for metered water. The fifty-five hundred fixture accounts are hold-overs, and are gradually being done away with. The houses on fixture rates are inspected and billed twice yearly. The metered consumers receive bills quarterly, but as a matter of service all meters are read monthly, and any excessive flow of water is called to the consumer's attention, that he may put a stop to it at the end of the first month. It is illustrative of the peculiar quirks of human nature, that sometimes consumers ask for a reduction on a water bill because we failed, on our monthly round of readings, to get into their locked-up premises and the leak went on for two or three months. Such people are taken care of by this paragraph:

"The Department will endeavor to notify consumers of excessive use of water by the monthly reading of meters, but failure to send such notification or inability to read the meter from any cause shall form no basis for allowance on a large quarterly water bill."

It is interesting to note that it costs as much in a year to make eleven thousand inspections in houses on fixture rates as it does to make ninety thousand meter readings.

One meter bill and one fixture bill only is presented to a consumer owning several pieces of property in one district, the detail being shown on the back of the water bill. All bills are made up in the water office and are sent, together with the commitment sheets, to the collector, from whose office they are mailed to the consumers. At the end of fifteen days, 5 per cent. is added to all unpaid bills, and at the expiration of thirty days

the water is shut off. Forty-eight hours prior to the shutting off, a notice is mailed from the collector's office as a final warning.

That most troublesome class of consumers, those who are always looking for a chance to collect something from the City, are pretty well fortified against in the regulations by paragraphs which set forth that the City does not guarantee constant pressure or uninterrupted service, and that it will not be responsible for any damages resulting from interruption of service, collapsing of hot-water tanks, shutting off without notice, dirty water, nor for conditions in consumers' pipes which cause trouble coincident with or following work done by the City on its pipes.

Were the public educated to understand that their water-works system is an institution which strives to give as much service as possible for the money which the public expends, there would be less and less need for rules and regulations, and it is to that end that we must all work. It is a hard proposition, however, especially in communities made up, as Lynn is, of a large proportion of foreign-born people. A great many of these people seem very apt in learning how to beat the Water Department out of money, but very slow in getting a viewpoint which will cause them not to want to do such a thing, to realize that it is their own business that they are trying to cheat.

Our great weakness in dealing with the troublesome ones comes from the fact that in Massachusetts water bills are not liens on property, and there has sprung up in Lynn a clique of operators who, by rapid transfers of property among several of the gang, leave us up in the air in regard to shutting off water to collect the unpaid bill, as of course the new owner cannot be held for water that the former one used. We have a provision which allows us to require a deposit in advance when we deem it necessary, but it is hard to give a reason why this should be applied until we have a record of an individual having at least one unpaid bill against him, so we are continually losing money in spite of such a provision. Many such people have no visible assets, and in nearly all cases the individual bills are too small to justify a suit. It certainly is a condition which there should be laws to remedy.

Much has been said about education of the public, and no one is a stronger believer in that than the writer, but certainly up to date, as a substitute for penalties and charges, it fails in a city like Lynn. Before using a 5 per cent. penalty on unpaid bills, there existed a chronic group of delinquents to whom the 20c. summons was a joke, and offers to test meters free to show our faith in their accuracy was met by a deluge of requests from consumers who in some cases had received bills less than a dollar above the average.

While many of the methods described above are stringent, it must not be forgotten that to the good fortune of water-works officials the vast majority of water consumers scarcely need to know that there is such a thing as rules and regulations.

Discussion.

Mr. Charles W. Sherman.* The whole backbone of the operation of a water-works system is in its rules and regulations, especially in so far as its relations with consumers are concerned. Mr. Newsom has done a real service to water-works men in putting on record some of the most important provisions which he has framed for use in Lynn, and which I am sure will be of great assistance to many of us in making the revisions that periodically become necessary in meeting conditions that our old rules and regulations do not cover.

President Macksey. In relation to trying to hold a man who passes title to property without paying his water bill, in Woburn we changed our contract so as to read that the party who made this contract agreed that we might, in the event of his non-payment, shut off the water not only on that property but on any other property which he might own in the city, which gave us a chance to collect some bills from real-estate owners who were holding to sell.

Mr. Henry A. Symonds.† What are the rights which a water department or company has, to shut off water for non-payment of water rates? That point was passed upon a few years ago by the Supreme Court in a case where the owner of the property had failed to pay the water bills. The owner claimed that the water was shut off illegally when done for the purpose of collecting the tax. He brought suit and, it was reported, recovered damages. At any rate, the decision of the Supreme Court was in his favor. I have been wondering whether we have been acting illegally in many cases in this matter, and under just what conditions we could shut off water and when not. I submitted that question to our counsel a short time ago, who made a somewhat careful study of it. His opinion was that we had a perfect right to shut off the water; that is, to discontinue furnishing water in the future, on the ground that a party was proving a bad customer, unless he had made the proper payments, but he was of the opinion that we did not have a legal right to shut off water for failure to pay for service which had been rendered in the past as a means of collecting; that our remedy was to bring suit.

Mr. Newsom. We have never, to my knowledge, experienced any particular difficulty in shutting off water. I, too, have talked the matter over with the city solicitor in connection with other regulations, — other things that we sometimes wished to do in order to make consumers act properly, — and he seemed to think that if the regulations are carefully enough drawn and are specific enough, and if in the contract which the consumer signs he agrees to be bound by those regulations, we should probably have no difficulty in carrying them out. That applies to most of them, I should say; but until such time as they are tested they accomplish

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a great deal of good, and you have sometimes to depend on the fact that the public will do almost anything at all reasonable rather than go to court; and as long as you keep your regulations within the bounds of reason I think you have a chance to get them by most of the time. As far as shutting off water goes, however, we have never had any difficulty in that line that I know of.

A PRACTICAL TALK ON SOME WATER-WORKS MATTERS.

GEORGE H. FINNERAN.*

[*September 10, 1920.*]

It is interesting to consider the changes which have occurred during the present generation in the methods and means of doing the work of a water-distribution system.

The automobile has replaced the horse, and while it has speeded matters it has brought its own troubles. The tapping machine, with its special sleeves and valves, and the valve inserting machine, have replaced the old method of shutting down, cutting out with hammer and chisel, and pumping.

Electrical thawing has replaced the slower and more tedious method of injecting hot water into the pipes. The automobile attachment for closing and opening large gates has made their operation easy and quick, — a big factor in general maintenance and in main-pipe breaks of serious consequence.

Electrically driven pumping units, largely of the centrifugal type, mechanical stokers, and mechanically operated valves have made pumping stations more efficient.

The various jointing compounds have to a considerable extent superseded lead, thereby saving bell holes, calking, and cost of material. In some parts of the country cement is now being used as a jointing material. Cast-iron water pipes are being manufactured and sold with lead joints in the bells, ready for calking.

The trenching machine under certain conditions is displacing the pick and shovel. Gasoline and electric power-driven pumps are employed where hand-worked diaphragm pumps formerly were used. The air compressor combined with pneumatic tools has replaced hand rock drilling and hand calking. The differential hoist with its duplex and triplex blocks is used to advantage in laying main pipe, displacing the rope tackle and the cumbersome winch.

The leak finder, pipe locator, gate finder, aquaphone, detectaphone, transmit-o-phone, geophone, sonoscope, sonograph, sounding rod, pitometer, manograph, and Venturi meter, all tend to facilitate the work of stopping leaks, minimizing waste, increasing revenue, etc.

Plunger piston meters have given way to the rotary and oscillating disk types, with more accuracy especially in small flows. The compound meter with its wide range of service has made it practicable to meter pipes with considerable variation in the rate of flow. Meter testing has been much facilitated by improved apparatus.

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The patented flanged couplings or dry couplings, as they are sometimes called, have to a large extent displaced the plumber and his solder joint.

Electric and acetylene lights have made night work practical. The hand flashlight has replaced the antiquated and dangerous candle and the smoky and smelling lantern. The oxyacetylene torch is every day proving itself to be a money saver by its ability to repair broken castings and metal parts that formerly were considered as beyond repair. The plumbers' torch has replaced the old charcoal furnace with its soldering iron. Gasoline and kerosene lead-melting furnaces are used where formerly wood and coke supplied the heat. The large blow-torch melts out the lead joint where in the old days a fire of wood or charcoal was built under the pipe.

Steam, slacked lime, charcoal, and the blow-torch are now used to remove frost from the ground. Calcium chloride, denatured alcohol, glycerine, and kerosene are applied to hydrants as anti-freezing materials. The natural heat of the ground is intelligently utilized to prevent freezing of meters and hydrants.

An improved type of force pump combined with up-to-date methods has made the clearing of stoppages easier and more successful.

The development of the telephone system has facilitated the direction of outside men through means of frequent communication between headquarters and near and distant points.

The development of the emergency gang has resulted in quick service to the public and the control of leaks and breaks with a minimum amount of damage.

The development of water-works associations, with their meetings and journals, interchange of opinions, recital of experiences, collection of data, the work of committees in standardizing specifications, the influence of the organizations in promoting beneficial and desirable legislation, etc., have tended in a very great degree to advance the ways and means of operating a water-works system.

The changes indicated in the foregoing have in almost every case proved to be an improvement and a step forward along the line of efficiency. They are, however, chiefly mechanical. In the labor end of the work, I regret to say there has been no great improvement either in quality or quantity. If it were not for the compensating effect of the many mechanical devices introduced into the work, and increased earnestness and energy on the part of the directing forces, I fear we should not have much to report under the head of results.

Especially during the last few years, labor as a whole has declined in zeal. It appears to have lost interest in the work. We do not see it displaying the initiative and the sense of duty that was usual in the old days. The newcomers do not have the manner of one intending to stay, to acquire experience and skill as a water-works man, and become part and parcel of

the system. Rather do they impress one with the idea that their service is to be temporary, a mere filling in while they are getting an easier and higher-class job. Possibly this may not be the case in private water companies where the management has a wider scope of selection and full powers to hire and discharge, but in municipal systems I think it will be found so.

There are of course good working men in every water-works system. They are usually of the old stock, and have been in the employ of the cities and towns for some time. They are the stand-bys, the real props, and without them matters would be well-nigh hopeless. They are fast dropping out through infirmity or death, and their replacement is a serious problem.

Contract work can be used to advantage in extending and relaying mains and other new work, but in general maintenance the work is of such a miscellaneous and complex character, and governed by conditions which cannot be foreseen, that men with special qualifications acquired by experience are necessary. Moreover, these men must be on hand at all times and under full control of the management of the plant. To fulfill these specifications a regular force of day workers is necessary, — men who have become attached to the plant with the intention of permanency. It must be practically their life work.

In a certain sense this is asking a sacrifice on the part of some men who might meet with opportunities in other lines.

Realizing this and understanding that the value of a man, with certain exceptions and limitations, increases with the length of time devoted to the service of the department, the management should treat their worthy men appreciatively, and generously recognize the value of their work.

In some cities and towns this is being done to a certain extent by pensioning the laborers and mechanics, but with my limited knowledge on this subject I am not aware of any provision being made to pension foremen or superintendents. This, to my mind, is not exactly fair. The average general foreman or superintendent in a municipal water works devotes his period of productiveness and maximum energy to the public service. After passing that period he is unfit to start in any new line of business and successfully compete with younger men. The very nature of his work is such that he does not meet with opportunities for advancement. He is confined to a certain routine and limited to a certain area of action. He cannot go far afield. He must hold himself in readiness to answer the call. It may come when he is in one end of the district or the other, when he is awake or asleep, when he is at home or in church, or possibly in the theater if he allows himself such a respite from his labors. For my own part, I have acquired the habit of calling up headquarters on the 'phone, whenever I am away from the office or home for any length of time, to learn what has occurred in the meantime. I recall one such occasion previously to entering the theater, when I was informed of a serious break in a 36-in. main in the downtown section. Had I omitted to make

this inquiry I should have sat through a performance for almost three hours blissfully ignorant of that which to a water-works man is a tremendously important event, namely, a bad break, in a large main, in a congested section.

This concentration of the mind on water works has a tendency to subordinate all other matters, and restricts our field of action to a limited extent. The consequence is that we do not get into the main currents of life, making contacts at various points with diverse interests, as do some men in other lines of work. Hence opportunities which usually come from such contacts are denied us, and those who are not well fitted for the work we are engaged in are unable to find our right places in the world. We continue as mere water-works men, doing the day's work with no expectation of recognition or reward, and only the satisfaction which comes from a faithful performance of one's duty.

However, to revert to the subject of a proper recognition of the value of the men's work, I must say that workmen have not fared so well in the water-works line as they have in others: I am speaking now for Boston. Ordinary unskilled labor in many cases that I know of has been paid a higher rate of wages on the outside than some of our own skilled men, and as for calkers I know of several places where contractors have paid them one dollar an hour. This has a very disquieting effect on our men, and unquestionably has diverted their interest from the work. So far as the remuneration of superintendents goes in these days of high wages and high cost of living, I feel safe in saying that it has not advanced proportionately with that paid to men holding positions of equal responsibility in other lines.

Before leaving this subject of labor I should like to call your attention to the self-assertion of men in recent years as compared with their docility in previous times. While I daresay it is not peculiar to those employed in water works, yet I cannot help observing it because it is so comparatively pronounced. Upon the slightest pretext a protest is made to this condition or that grievance. Extra attention is paid to the classification of the work. Men are inclined to specialize more than ever. One has to be careful in asking a handy man to lay a few bricks or cut some stone, or repair artificial stone sidewalks; or in asking a carpenter to tack some sheet iron instead of a board to a wall, and so on. You probably will be told by the man that he is not a bricklayer, or a stone-cutter, or a mason, or a sheet metal worker. You may also be told, "I don't get the money," or "I don't care to scab."

All this is part of the doctrine of unionism, and from certain standpoints is perfectly proper, but it does sometimes slow up the work, especially when one is particularly anxious to do a quick job.

Great care and attention is now necessary to keep the men working harmoniously and coöperatively. Temperament is ever present. A superintendent has to be a near-psychologist, to diagnose the mental oddities

found among the men. There are some men who work better alone than with others. There are some men who expect to be told what to do, step by step. Others resent such interference. There are individual preferences about working together, some likes and intense dislikes. There are suspicious men and notional men. There are tricky and sneaky men, and there are downright dishonest men. There are stupid men and slow men and lazy men. There are destructive men and dangerous men. There are chronic whiners and men unable to stick for any length of time to any particular kind of work. There used to be drunken men, but I am glad to say that since prohibition we have very few with that failing. When the bootleggers are exterminated we shall not have even that few.

Happily, there are many men who are normal and well-balanced, but it requires much ingenious effort to combine the numerous diverse dispositions into a well-working machine.

As for politics, those of us who are in municipally-owned systems know that it is an ever-present factor operating usually to the detriment of the service. It is so common that we have almost accepted it as a necessary evil. Just so long as the individual is willing to advance his own selfish interests, at the expense of the community, will municipal work suffer a handicap and fall short of real business efficiency. In Boston, I am glad to say, matters have improved within the last few years, and the situation in this respect is quite hopeful.

There is another disadvantage which the work of a water-distribution system endures, and that is its hidden nature. We are underground workers. Immediately upon completion of our work we cover it with five or six feet of earth. We cannot display our wares. I have often seen a very fine example of pipe work where the pipe layer was so proud of it that he delayed filling in until somebody in authority could view it. It seems too bad that the public does not see more of our work. It is our lot, however, that we are seldom thought of except upon rare occasions when the faucet is open and the usually never-failing gush, of one of the most important substances in the world, is missing. The work of the paving, street cleaning, and sanitary branches of the public service is continually before the eye. The public is in contact with it through some of the senses, and consequently it is catered to. It is like the handsome daughter of a family, dressed up, kept in the foreground where all may behold her charms, while her plainer and more utilitarian sisters, water and sewerage, are kept in the background, very often furnishing the wherewithal for the embellishment of their fairer sister.

I realize that my remarks have a pessimistic tone, but we all know there is a bright side to the picture; that in water works, as in all other work, there is joy in the accomplishment. We are conscious of rendering the public a great and necessary service. We are constantly meeting with problems and obstacles, but upon applying ourselves to them they flatten out and disappear, and in direct proportion to the greatness of the difficulty

is the glory and satisfaction of achievement. This swimming against the current and sailing against the wind is the best means of developing our character and capabilities, and we should be thankful for the opportunities of this sort which our line of work presents.

In connection with the question of compensation, I thought it would be of interest to others to know what we are paying our workers in Boston. We receive frequent inquiries on this subject.

Laborers receive $4.00 a day of eight hours' duration; calkers and repairers, $4.25 to $4.50; pipe layers, $5.00; plumbers, $4.50; chauffeurs, $4.50; machinists, carpenters, blacksmiths, $5.00; pavers, $5.00; meter repairers, $4.50; drillers and assistant machinists, $4.00 to $4.50; and a variety of rates for bricklayers, stone cutters, electricians, storekeepers, yardmen, etc., ranging from $4.00 to $6.60 a day. Foremen, inspectors, and clerks are paid salaries ranging from $4.50 a day to $2 300 per year. Meter readers are paid $1 400 to $1 500 per year, and engineers and superintendents $1 100 to $5 000.

All overtime — that is, all time in excess of eight hours — is paid for at the rate of time and one-half except on legal holidays, when the men who work and who receive day wages are paid double time. Salaried men who work on holidays are allowed time off. All men who work Saturday afternoons are allowed time off and are not paid extra. If a man should work Sunday on a charged job he is paid double time. The emergency men work seven days a week and receive only straight time except for holidays, when they receive double time. All men receive two weeks' vacation without loss of pay. Also, in the event of the death of a father, mother, brother, sister, son or daughter, they are allowed three days without loss of pay to attend to funeral matters. All laborers and mechanics receive a pension of $360 per annum after working twenty-five years for the city and having reached the age of sixty, and having been pronounced by an examining physician to be unfit for work.

There is another provision which authorizes the City Council to retire a laborer or a mechanic upon a pension of $360 per annum after fifteen consecutive years of service, with no age qualification, but with the requirement of a certificate of disability from an examining physician. Before becoming operative the approval of the mayor has to be secured.

Veterans of the Civil War are retired at any age upon half the pay they are receiving at the time of retirement. Disability is necessary in this class as in others.

A retiring board consisting of the city auditor, city treasurer, and the mayor, decides finally on all retirements and they become operative only after said board gives its approval.

Automobiles.

There is no question but what the automobile is a permanent institution in all water-distribution systems. It has "speeded up" the work

and increased the capacity to serve. Its advantages are so obvious that it is superfluous to state them. It is a machine, however, and notwithstanding the efforts of the manufacturers to simplify its construction and make it foolproof, it is complex and contains many parts which get out of repair and cause delay and interruption to the work, usually at the most inopportune time. This breaking down is so certain that it is necessary in order to maintain uninterrupted service to have a reserve equipment. Just how much this reserve should be is a question depending on local conditions. I have heard it placed as high as 20 per cent. In other words, one fifth of the total number of vehicles should be kept in reserve to replace any of the remaining four fifths which might break down. In my opinion, this is placing the reserve figure rather high. In Boston we have been able to keep the equipment going with slightly less than one half of that. I must admit, however, that during short periods of stress we could have used a few more autos. Accidents, like other happenings in the world, appear to be more or less epidemic.

We have in the Boston department about 35 autos, mostly Ford runabouts for passenger transportation and Ford one-ton trucks for materials. We are not entirely motorized, as there remains provisions to be made for heavy hauling, — three to five tons, now cared for by horses, and there are kinds of work, like patch paving for instance, where a horse and wagon is more economical. In such work a horse and wagon carrying tools and materials stands around waiting on the men. I find that where there is much waiting an automobile is not economical. You get the best results by keeping it moving as much as possible with a minimum amount of time spent in stop-overs. To properly do this it is necessary to prepare its work ahead of time; or, if that is not possible, have it call up headquarters upon the completion of each job and receive directions for its next move, which very often may be conveniently near the location of the auto and thus save doubling back to the spot after arriving at headquarters.

In our "off-and-on" work, which consists largely of shutting off services to permit private plumbers to make repairs, and afterward turning on, this method of telephoning to headquarters is almost indispensable. It is a requirement in our emergency service and is found of much advantage otherwise.

The trouble with automobiles, as with other branches of the work, is the personal factor. If we could get men who had a mechanical conception of the automobile combined with a careful and considerate make-up, the cars would give much service with a small amount of trouble. We find, however, that many men who drive cars do not understand the principle of the gasoline engine. They do not know the "why" of this or that part. They are not sensitive to the little warnings which the machine gives out preceding its eventual breakdown. They are not sympathetic towards its eccentricities. They simply start the car, steer

clear of obstacles, go as fast as they can, and stop in as short a length as possible. Thus will they continue until something occurs to prevent the car from working properly and then there is a job for the repairers. They take the car given them in place of the disabled one, and repeat the operation. We try, of course, to show them the trouble and explain the cause, but somehow history repeats itself.

We find it necessary to pay strict attention to the oiling and proper inflation of the tires. Partial deflation of tires shortens their life considerably. We have a night man whose duty it is to inspect each car in the garage. If he finds any serious trouble or defect he places a tag on the car forbidding its use the next day, and reports the trouble in the morning to the auto repairers. He puts oil into the crank case, attends to any flat or partially flat tires, fills the gasoline tank, turns down the grease cups, cleans and polishes some of the cars, puts water in the radiators, etc. In the morning one of the repairers arrives before eight o'clock and starts up some of the obstinate cars, of which there are always a few, especially among the Fords and during cold weather. The idea is to have the car ready for immediate use when the day's work begins.

Many of our cars are driven by the men who use them; for instance, the district foremen drive themselves, the plumbers and meter repairers likewise; so also the " off-and-on " men, the engineers, myself, and even the division engineer, the head of the department. We try as far as possible to eliminate dead weight on the cars in the form of chauffeurs who only drive.

We keep the usual records of oil, gasoline, tires, upkeep, etc., but I find that while such records are valuable and necessary, yet they do not tell the whole story when used for comparison with the mile as a unit. There are miles and there are miles. Some of our cars are used exclusively in the congested parts of the city; some in the suburbs. A mile in one section means much more than a mile in the other. Stopping and starting necessary in the downtown streets, the bad pavements in some sections, the hills in other sections, all tend to influence differently the wear and tear on the tires and machinery and the consumption of gasoline and oil. There are such things as hard miles and easy miles. If you will notice, the tire manufacturers are not adjusting on the basis of numerical miles. They wish to know if the tire was on the rear or the front wheel, and they inspect it closely to observe whether or not the reported mileage was of the hard, backbreaking, abusive kind, or of the smooth, velvety, park-road brand. It makes a difference.

One thing is a certainty, in connection with the upkeep of autos, and that is, it pays to buy the best tires, the best lubricating oil, and the best quality of gasoline. It pays to watch the cars closely and continually, repair them at once if there is indication of defect, — do not delay. Watch the tires for under-inflation. Compare the records of the different cars, making allowances for the various conditions under which they are used,

and watch the man who drives the car and discover if possible his weaknesses and mistakes and correct them in the proper manner. Automobiles cost a lot of money to keep in service, and they should be worked to the maximum.

Blow-Offs.

To use the expression of our workmen, the blow-off is a great thing.

It consists of a three-way branch or tee inserted in the main line, the branch lead being 4, 6, 8, 10, or 12 in. in diameter, according to the size of the main of which it is a part. The branch lead is usually off the bottom of the branch so as to drain the pipe completely, and is controlled by a valve. It is connected with a sewer or waterway of some kind.

Originally the blow-off was intended as a cleansing agent through which bad water might be blown into the sewer. The velocity of the flow was supposed to detach the accumulations of the interior surface of the pipe and carry them into the sewer. We find, however, that it is difficult to confine the "riling up" effect of the fast flow to any local section, and instead of improving conditions we sometimes make matters worse, especially when we are thoughtless enough to "blow off" on a washing day or in the vicinity of some large laundry or dyehouse.

Another use planned for these fixtures was to drain the contents of the pipe into a sewer or other channel, and thus make the work of repairs or replacement, or the plugging of an abandoned service connection, easier by getting rid of the water without pumping.

In a system as old as that of Boston, with a surface water supply that easily makes rust, the interior of the pipes is more or less filled with corrosion and other growth. The seats of the valves are soon filled with the same material, and regardless of whether they are run up and down periodically it is a difficult matter in many cases to close them tightly. In such cases the blow-off is of much help, by draining off the leakage and keeping it away from the point of work where it would of course interfere with the making of the joints. That is why our men call it "great" and demand more of them.

In parts of our high-service system where it supplies only sprinkler pipes and a few service connections to extra high buildings, we have been put to much trouble recently because of the absence of blow-offs. They were not installed in such lines, and now when occasionally it becomes necessary to repair a gate, plug an abandoned service connection, or drill a new connection dry, — that is, where we are unable because of insufficient space to use a regular drilling machine and we shut down the main and drill into it with a simple brace and bit, — we find difficulty in getting rid of the locked-in pressure. It requires some time for this pressure in a long section of main to spend itself through a $\frac{5}{8}$-in. hole or even a smaller hole, as in the case of the dry drill. It becomes necessary in such cases to let it flow out and use the pump, or if we can find some fairly good-sized con-

nection leading off the main into some building we open it and draw off the excess water.

In the case of leaky gates, however, there is nothing that can be done except to shut back of the bad gates or "fight" the water — as our men express it — with pump, and quick work in making the joint helped out by a clay dam.

There are other things, however, to be considered in connection with a blow-off. It is a potential danger of waste and low pressure. Unless great care is exercised a blow-off is sometimes opened by mistake, or left open, or only partially closed. It continues in this condition until discovered. In the meantime much waste has occurred and increased pumping necessitated to maintain the pressure.

The very nature of the blow-off requires it to be placed at a low point in the line of pipe. Where sewers are not available it is customary to set the outlet in waterways, dikes, culverts, and even in the harbor wall. Care must be taken in such cases that the blow-off be kept closed when the tide is high or when the water level is up to the grade of the blow-off. It is an easy way to get infected water into the main. It is of course possible to flush the main, but the danger lies in overlooking the occurrence.

Where they enter sewers and sewer manholes care should likewise be taken to guard against the possibility of the sewer filling and backing up because of stoppage or a heavy storm. One cannot be too careful on this point. Check valves may be used as a protection but they cannot be depended upon absolutely in such an important matter. Personal attention of the most careful kind is the only preventive.

Filling a Main Line.

To the average workman, filling the main line is a very commonplace affair, but to the competent and painstaking man it is a very important matter and requires time measured by the diameter and length of the main. The important thing is to get rid of all the air. In ordinary distribution mains to which hydrants are connected, this is not a hard matter, as by opening one or more hydrants the main pipe is vented and the air allowed to escape as the water displaces it. In large transmission mains, air valves placed at high points in the grade line are the only means of letting out the air. There should always be at least one air valve of at least 2 in. in diameter in each section between gates and located at the highest point of the pipe line. If the grade line of the pipe is undulating, a valve should be placed on every summit. If gates are located at high points it is well to have an air valve close to the gate on each side.

A man should be stationed at each valve in the section to be filled, with wrench or key to control the valve when the air is expelled and the water comes. Not every man is suitable for this job. The roar of the air escaping from a large main has a bad effect on a nervous man, and he is

inclined to shut the valve before all the air is out. As the filling of the pipe nears completion the air and water rush out alternately, caused by the breaking down of air pockets and the surging of the water in the pipe. If the manhole in which the valve is housed should become filled with water, these rushes of air and water are apt to cause violent splashes and consequent wetting of the man with the wrench. A timid man may desert his post or allow the wrench to become displaced on the air valve, and it is a hard matter sometimes to replace the wrench on account of the agitated state of the water in the box or manhole and its increasing pressure. An experienced man can usually tell when the air is all expelled. The discharge becomes more uniform and the water loses its white, foamy appearance.

If there are small by-passes around the large gates the filling of the pipe should be done through one of them, choosing the low end of the section. If there are no by-passes there is usually at least one connection of smaller diameter than that of the main to be filled. Fill through that. If there are no by-passes or connections, open one of the large gates a very little and admit the water very slowly from the lower end of the section if possible. It is usually a hard matter to open a large gate with the pressure on one side only. Care should be taken to avoid breaking the gear or the screw.

I have observed the filling of a section of large main through a 12-in. connection on the high end of the section. The only air valve was located on that end also. The inrushing water flowing down grade through the empty pipe caused the outside air to be drawn in through the open air-valve, thereby reversing the natural order of things. When the pipe began to fill, the water within started to surge violently, and there were periods when the air was sucked in from the outside, followed by periods when the air and water mixed was driven out with great force. This continued for some time, and it is a question whether or not the air was completely forced out. Probably when the gates were raised it worked its way through the system, gradually finding its way out through taps in buildings.

It is right here that the danger lies. If the air is not completely driven out of the pipe it will find its way out somehow, and it is often the case that it works its way out through the top of a joint or through the stuffing-box of a gate valve. This means, in the case of the joint, a weakening of the same; and a leak starts then and there. It is not an unusual thing that when a large line is shut down and emptied or partially emptied to make repairs, not long after it is turned on a leak is reported in the street over the line. This happens notwithstanding our efforts to have the line properly filled, showing how difficult it is to rid the pipe line of all the air. Joints are often blown out by air.

We see the effect of air on the dial of the pressure gage, which shows violent oscillations of the pressure indicator. The collapse of air pockets

in the pipe sometimes produces powerful concussions which have a bad effect on the pipe line and cause a movement in the same at some weak point.

It is therefore of great importance that the utmost care be exercised in filling pipes. Do it slowly. If possible, let it dribble in. The trouble is usually caused by impatient men who will not wait for the line to fill slowly.

In this rather rambling talk, on a few disconnected matters that we meet with in the day's work, I realize that I may not have added much to the general fund of information, but I feel that I have at least implanted a few thoughts in your minds which may result beneficially, one way or another.

DISCUSSION.

W. C. HAWLEY.* I think that Mr. Finneran has covered the ground very completely. In our pipe system we occasionally find a gate valve which cannot be closed because of the accumulation of sand, etc., in the bottom of the valve, which prevents the gates from seating. By closing and opening the valve several times, sometimes as many as a dozen or fifteen times, we are generally able to blow the foreign matter out and close the valve tight. Our instructions to the men, in such cases, are to close the valve until it stops, but not to attempt to force it home. By repeated opening and closing we can gain a fraction of a turn each time, and soon the gate can be closed. We do not, of course, open the valves wide each time, but just enough to raise the gates from the sand, etc., which has collected in the bottom, so that the current of water passing through will tend to force the sand out of the bottom of the valve.

*Engineer for Pennsylvania Water Company.

INSTRUCTIONS TO EMPLOYEES AT PUMPING STATIONS AND FILTER PLANTS.

DOW R. GWINN.*

[*September 8, 1920.*]

Human nature is very much the same in Indiana and Illinois as it is in New York and Oregon. The tendency is to move along the line of least resistance, — to do things in the easiest way. There are cases where the easiest ways and efficiency are not synonymous terms. In operating water plants the author has tried to find the best way of doing things, and then to adopt them as standard methods, even if they are difficult, and holding to them until better ways have been found. After methods have been adopted it is discouraging to find, later on, that they are not being observed by assistants. On inquiring why certain methods have been discontinued, the usual answer would be, " We don't do it that way any more." And further inquiry would not disclose why or when the method was discontinued. The idea of printing instructions was then tried; it has worked very well. There is an advantage in having a particular time to do certain things such as cleaning the heater, blowing down the boilers, taking indicator cards, making evaporation tests, etc. The instructions are typewritten and are kept in a loose-leaf binder. Changes can be easily made and additional sheets may be readily added. No method is so sacred but that it can be changed by the manager. The employees are encouraged to suggest better methods, and when tried and found to be advantageous they are substituted for old ones. Each employee is supposed to read the instructions once a month; he may select his own time while on duty for the reading. A sheet of properly ruled paper is enclosed in the file, on which are the list of employees, and each employee records the date when he reads the instructions.

The Terre Haute plant takes its supply from the Wabash River, and is a direct pumping plant, there being no standpipe or elevated reservoirs which could be used if pumps were not in operation.

For pumping into the distribution system there is a ten-million vertical triple expansion and a six-million vertical compound; also, smaller pumps. For delivering to the sedimentation basin there is a centrifugal pump operated by a compound high-speed engine connected with a rope drive. Steam is generated in water-tube and fire-tube boilers with hand firing. A vacuum pump for exhausting air from the suctions of the principal pumps is a part of the equipment. There are 22 mechanical pressure filters. There is a sedimentation basin with sufficient capacity for

* President and Manager Water Company, Terre Haute, Ind.

approximately two to five hours subsidence. This is only used when the turbidity exceeds, say, 60 on the Jackson turbidimeter, or about 55 per cent. of the time. The turbidity of the river water ranges from 25 to 3 000. The pumps work against 70 lb. domestic pressure and 125 lb. fire pressure. The available fire pressure at hydrants in business or high hazard district is 100 to 110 lb. While the fire department is equipped with pumpers, they are seldom used, the pressure from the plant being usually sufficient. There are 100 miles of mains, 62 per cent. being 8 in. and larger diameters. There are 1 155 public fire hydrants. There are 8 240 consumers; 97.7 of all service pipes are metered, including private fire lines for automatic sprinklers.

THE TERRE HAUTE WATER WORKS COMPANY.

Names.	1920.											
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.

These instructions are to be read monthly and the date of reading recorded in the proper column.

Suggestions for the improvement of the service are respectfully invited.

No man can know too much about his work.

Please bear in mind that you are guarding the water supply of your home city.

Be faithful in the discharge of your duty.

At the plant a program clock is provided, which summons the attendants every half hour to examine the water; this is just a visual examination of the raw and filtered water, and a record of the appearance of the water is made. This is necessary because of sudden changes in the turbidity of the raw river water.

A record of fire alarms is kept, showing the length of time extra pressure is maintained, increase in pumping rate, time of receiving alarm and strike out; also, hydrants used and condition after fire. Inspectors answer alarms received from high hazard districts during day, and second

THE TERRE HAUTE WATER WORKS CO. Day, *Thursday*. Date, *July 15*, 1920.

At signal observe both raw and filtered water, and record appearance of filtered water: O.K. — All right. S. — Slight variation from standard. M. — Medium. B. — Bad.

If any observation is unsatisfactory, DO SOMETHING, AND DO IT QUICKLY. Use No. 5 for immediate results.

Record changes made by numbers as per margin, but only changes made for correction are to be recorded.

If, for any reason, observation cannot be made within five minutes of the time, leave space blank.

Each engineer should compare time of recording clocks with correct time during his watch.

W. E. TAYLOR, Chief Engineer.

METHODS OF CONTROL.

1. Use of Engine No. 5.
2. Turn in basin.
3. More water from basin.
4. More alum in water to filters.
5. More alum in water to basin.
6. Reduce rate of certain filters.
7. Wash small filters
8. Wash large filters.

Time.	Appearance.	Observer.	Cl. Manometer Reading.	Changes Made.	Time.	Appearance.	Observer.	Cl. Manometer Reading.	Change Made.
A.M.					P.M.				
12.30	*O.K.*	*M.*	*30*		12.30	*O.K.*	*R.*	*32*	
1.00	*O.K.*	*M.*	*28*		1.00	*O.K.*	*R.*	*34*	
1.30	*O.K.*	*M.*	*20*		1.30	*O.K.*	*R.*	*34*	
2.00	*O.K.*	*M.*	*20*		2.00	*O.K.*	*R.*	*34*	
2.30	*O.K.*	*M.*	*20*		2.30	*O.K.*	*R.*	*34*	
3.00	*O.K.*	*M.*	*20*		3.00	*O.K.*	*P.*	*34*	*Charts*
3.30	*O.K.*	*M.*	*20*		3.30	*O.K.*	*P.*	*30*	*O.K.*
4.00	*O.K.*	*M.*	*20*		4.00	*O.K.*	*P.*	*30*	
4.30	*O.K.*	*M.*	*20*		4.30	*O.K.*	*P.*	*30*	
5.00	*O.K.*	*M.*	*20*		5.00	*O.K.*	*P.*	*25*	
5.30	*O.K.*	*M.*	*20*		5.30	*O.K.*	*P.*	*25*	
6.00	*O.K.*	*M.*	*20*		6.00	*O.K.*	*P.*	*25*	
6.30	*O.K.*	*M.*	*20*		6.30	*O.K.*	*P.*	*25*	
7.00	*O.K.*	*B. W.*	*20*	*Charts*	7.00	*O.K.*	*P.*	*25*	
7.30	*O.K.*	*R.*	*20*	*O.K.-*	7.30	*O.K.*	*P.*	*25*	
8.00	*O.K.*	*R.*	*35*	*B. W.*	8.00	*O.K.*	*M.*	*25*	
8.30	*O.K.*	*R.*	*32*		8.30	*O.K.*	*M.*	*25*	
9.00	*O.K.*	*R.*	*32*		9.00	*O.K.*	*M.*	*33*	
9.30	*O.K.*	*R.*	*32*		9.30	*O.K.*	*M.*	*33*	
10.00	*O.K.*	*R.*	*32*		10.00	*O.K.*	*M.*	*33*	
10.30	*O.K.*	*R.*	*32*		10.30	*O.K.*	*M.*	*33*	
11.00	*O.K.*	*R.*	*32*		11.00	*O.K.*	*M.*	*33*	*Charts*
11.30	*O.K.*	*R.*	*32*		11.30	*O.K.*	*M.*	*33*	*O.K.-M.*
NOON.					MID.				
12.00	*O.K.*	*R.*	*32*		12.00	*O.K.*	*M.*	*33*	

GENERAL OPERATING RECORD.

Pounds of coal, *23 190+5%, 1 150=24 340*
Pounds of ashes *2 620*
Percentage of ashes *11.3*
Gallons, high service* *5 605 600*
Gallons, low service* *5 605 600*
Gallons per pound of coal *241*
Turbidity at 7 A.M. *550*
Stage of river *5.6*
Rainfall, inches .....
Temperature of water ..... *26° C. = 78° Fah.*
Basin on, hours *24*
Alum, grains per gallon *3.07*
Chlorine, pounds per million *4.6*
Repairs and principal work outside of operation:
Per cent. wash water *6.1*
Alkalinity, parts per million *140*

Total hardness — soap method, g.p.g. *13.5*
Average rate per day per acre *104*

BACTERIOLOGICAL

Raw water per c.c. at 37° C. *3 000*
Filtered water per c.c. at 37° C., *20=99.3%* efficiency
Raw water, B. coli, 1 c.c. sample ..... +
Filtered water, B. coli, 1 c.c. sample .. —
Filtered water, B. coli, *5*—10 c.c. samples,
Filtered water, B. coli, No. 10 c.c. samples, positive *0*
Filtered water, B. coli, No. 10 c.c. samples, negative *5*
Filtered water, No. 10 c.c. samples showing gas ..... 24 hrs., *0* 48 hrs., *0*

* No allowance for slippage.
NOTE. — In above table, italics indicate actual records.

alarms at night. Engineers and firemen are on duty eight hours; that is, they are off duty sixteen hours per day for six days and the seventh day they are off twenty-four hours. Monday is change day, when each man moves up one watch, the duties during the eight hours being performed by other employees. The changes are made at 7 A.M., 3 P.M., and 11 P.M. Employees are given two weeks' vacation with pay. Baths are provided for the men, also books on engineering and technical publications. The grounds on which the station is located were laid out by a landscape gardener and are very beautiful. A fine tennis court is provided. Long periods of employment are the rule, one engineer having recently completed thirty years of continuous employment. The company arranges and provides for an annual picnic on the station grounds, for employees and their families.

The instructions which follow have been found to be satisfactory for the Terre Haute plant, and while they would not be suitable in every particular to any other water-works plant, they may be suggestive and valuable to other operators.

THE TERRE HAUTE WATER WORKS COMPANY PUMPING AND PURIFICATION DEPARTMENTS.

General Instructions.

These general instructions are not intended to take away the power and obligation of the employee to meet his work with personal judgment and efficiency, but rather to assist by such rules and suggestions as seem necessary and helpful.

Bear in mind that it is up to us to maintain the standard; that it is our duty to *furnish good water every minute* and adequate fire service whenever it is called for; that the manager is depending upon his fellow-workers to do their part, and that he has confidence in them; that in emergencies it is not a question of spending a few dollars in order to get results, for the standard must be maintained regardless of cost.

Fire Alarms (Engineers). The big, general thing to remember is to "play safe." That is, to consider the location of the fire and its probable or possible magnitude, and to promptly take any action that may seem necessary to furnishing an adequate supply of water at proper pressure and maintain the quality of the water; to this end it is better to take much precaution, such as notifying the chief engineer and the assistant chief, calling out an extra fireman or station helper, having fire lighted in extra boilers, getting an extra engine ready, etc., rather than fail in any particular because of lack of having done these things.

In case of a serious fire or general alarm, notify chief engineer and assistant chief engineer; if the fire is at night, notify F. M. Johnson, general foreman (if communication by telephone direct cannot be made,

use Western Union service, both telephones No. 32); get Holly engine warmed up and ready for action; consider the matter of whether there are enough boilers in use and whether extra help is needed in boiler room.

Engine No. 5 for Emergency. Engine No. 5 is the quick-acting emergency and peak-of-load engine. This engine should be put into service at once, in case of any trouble with Allis or Holly. No. 5 can be put under full load, if necessary, *in one minute;* the best way to handle the engine for this quick action is as follows: Both steam valves should always be left hooked up; then, first crack throttle slightly; proceed at once to open water-injection valve; unlatch one steam valve, and go ahead. Each engineer should practice handling the engine until he can safely and surely get under full load in one minute as stated.

Call Bells at Allis. The call bells in lower boiler room and in filter room, with control at Allis engine are intended for use of the engineer when wanting help and not wishing to leave engine; they will sound continuously until stopped.

Call Bell at Observation Sink. This bell may be answered and observation noted by the engineer, filterman, or helper who happens to be nearest at signal. Do not, however, record any observation unless you actually take it. Do not indicate as " O.K." unless water is clear. Smoky water is not satisfactory. For instance, if you record an observation at three o'clock and notice a blank for two-thirty, do not go back and record two-thirty as an observation. Any signals that have been missed, leave them blank; if the observation signal is not operating properly, it should be reported by the engineers to the chief engineer. A signal answered within five minutes after its stated time may be properly recorded.

Report Trouble or Unusual Occurrence. Any particular trouble or unusual occurrence at the plant, in the absence of the chief engineer, should be reported as soon as practicable, by telephone, to Mr. Taylor or Mr. Ranbarger; also, a written report of the matter should be left by the engineer on watch for the chief engineer, before going off duty.

Suspicious Behavior of Engine. Any of the engines developing any trouble or suspicious behavior should promptly be placed under control of the throttle or shut down, as may seem necessary. If placed under the throttle, the engineer should signal filterman or fireman for assistance.

Coppus Blowers and Low-Pressure Alarm. These are to be tested out for operation each week, and recorded on weekly report sheet, with date of test. As a general rule, they will be tested and recorded by the assistant chief; but, if for any reason, he does not do so, the engineer making out weekly report on Friday night will test and record same, signing his name.

Inspecting Recording Gages, etc. The engineer on watch will, immediately after coming on, inspect water-pressure gage on Allis engine, and general condition of all machinery in operation; a little later, he will inspect recording steam-gage and tachometer chart for proper operation,

and also for proper time-setting, and record observation on daily report sheet. Engineers will sign tachometer gages in spaces they are on duty.

In addition to taking revolution counters at midnight for the daily pumpage, the engineer on watch will take the counter on No. 7 at 2.00 A.M. and at 4.00 A.M. each morning, and record the average r.p.m. for the two-hour period on the daily report, also on the graphic chart posted on wall of engine room. Record manometer reading of liquid chlorine apparatus, as provided for on daily report sheet. Take temperature of No. 3 engine room daily, noon and midnight during winter months, and record on weekly report.

Consider the Boiler Plant. The engineer on watch should always know exactly what boilers are in use; what, if any, are banked and held ready for emergency; whether or not any are out for cleaning; in short, have exact knowledge of the entire boiler plant. To this end, it is a rule that each engineer *before taking his watch and before the preceding engineer has left, shall personally inspect* CONDITIONS BOTH UPPER AND LOWER BATTERIES OF BOILER; AND OBSERVE the conditions at every boiler, whether in use or out of use. If a boiler is banked, note the condition of the banked fire, the steam pressure, the height of water in gage glass, the coal supply in car, etc. If any of these are not right, have them corrected as soon as possible. If, in the judgment of the engineer, there are not enough boilers under steam to meet probable demands, he should report to the chief engineer or assistant chief, and if he cannot do this, he should have such changes made as seem necessary or prudent. As a general rule, if the basin is in service and Stirling boiler is in use, one or more of the lower boilers should be under steam; in hot, dry weather, with heavy pumpage, all the boilers, not out for cleaning, should be under steam.

Consider the Fireman. If any change in operation involves more steam use, such as putting additional engines in service, the fireman should receive ample and definite information in time to be prepared for such increase in steam consumption.

Fire-Alarm Reports, etc. A written report on the special blank is to be made of every fire alarm, showing time received, pressure, increased pump speed, etc. In addition, the office should be notified at 7.00 A.M. of all fire alarms received during the preceding night.

Record should be made daily on the weekly report by the engineer who receives the Gamewell alarm test at 12 noon. If test stroke does not come at 12 noon, the chief of the Fire Department should be notified at once.

During cold weather, when the automatic sprinkler pipes in exposed places are empty, the air pressure on same should be recorded twice daily on the weekly report.

[Copy of Letter dated August 15, 1910.]

To Our Employees, — We wish to call your attention to figures furnished us by the Industrial Board regarding the number of eye accidents reported in the state of Indiana in the last ten months; 2 852 men have risked the loss of the sight of one or both eyes; many of them have lost their eyes.

The following is an extract from their report:

"Approximately 10 per cent. of accidents reported during the period of September 1, 1915, to July 1, 1916, were eye cases. On further analysis, these accidents show that they are largely to be classed as preventable accidents. Approximately 20 per cent. of the eye cases arose out of the operation of emery wheels, and the use of goggles would have prevented most of them."

The goggles which we provide remove the risk which you take of serious injury to your eyesight.

Your foremen have been instructed to see that all of the men who require goggles in their work are regularly wearing them. Save yourself from suffering and impaired usefulness by helping us to prevent eye accidents in the plant. This you can do by taking care to wear goggles whenever you are doing work from which an eye accident is likely to result.

THE TERRE HAUTE WATER WORKS CO.

SPECIAL FOR CHIEF ENGINEER.

Sand Catchers. They are to be blow-out the first day of each month, and the conditions found are to be noted on daily and weekly report sheet.

Feed Water Heater. The feed water heater is to be cleaned about the fifteenth day of January, April, July, and October, and the conditions found are to be noted on daily and weekly report sheets.

Cleaning Condensers No. 6 and No. 7. When the condensers are cleaned, the time of cleaning and their conditions should be noted on the daily and weekly report sheets. When convenient, the condenser should be tested for leakage.

Indicator Cards. Indicator cards shall be taken about the fifth day of each month from engines No. 6 and No. 7. A set of cards should be sent to the office.

Coal. Coal cars shall be unloaded by day labor and a record of the cost kept.

River Soundings at Intake. Soundings in river bed along intake line, and extending out to the opening in river, should be taken each summer at low water, and a profile made on basis of low-water mark.

Filter Manifolds. Two filter manifolds of each size shall be kept in stock.

Automatic Sprinklers. Thoroughly inspect automatic sprinklers at the station in November of each year and send written report to the office.

Boiler Feed Pumps. These and the injector should be examined weekly and their condition reported.

Feed Water. Test feed water for soap hardness weekly and report same.

Evaporation Test of Boilers. Boilers to be tested monthly to determine evaporation per lb. of coal; the Stirling and Battery No. 3 to be tested alternately.

RULES AND SUGGESTIONS FOR FIREMEN AND BOILER ROOM HELPERS.

For Firemen.

Upon coming on watch, immediately observe steam pressure, water level in boilers, and general conditions. Blow down water from water column to be sure it is working properly.

All coal and ashes are to be weighed, and the time of coal loadings to be entered upon report sheet; the back weighing to be made at end of each shift, and the back weight to be charged to the fireman coming on duty.

After boilers have been cleaned and in service four (4) days, they are to be blown down once each day thereafter at about 8.00 or 9.00 o'clock in the morning. The engineer on watch is to be called at this time, and the extent and method of blowing down is subject to his approval.

Flues to be blown twice each day, on the first and second shift, as soon as convenient after coming on duty.

Any defect in any boiler, steam pipe, feed pump, or any apparatus in the boiler room, should be reported at once to the engineer on watch.

In the event of heavy call for steam, such as a large fire, and the fireman thinks he cannot hold steam with the boilers in use, he should report to the engineer at once.

Firing Methods.

Although it is not intended to lay down any hard-and-fast rule for firing, nor to discourage individual method, if such method can be shown to be better than these, yet it is thought that a very good method of procedure is as follows:

Keep grates fairly clean, and preferably so by the use of shaker grates. (Although it is known that with some coal and conditions of fire, it may be necessary to clean with slice bar and hoe.) Fire at rather frequent intervals, *say seven to ten minutes* — firing at long intervals, say twelve to fifteen minutes, *is not good practice and is* not approved — then manage damper and quantity fired, so that the fires will not burn down dead, and leave air holes at the time of next firing. In general, the least damper opening and draft you can use will be found most economical. When the draft is so great that fire burns down in holes, then heat is lost, simply by heating the air drawn in at such points, and does no good whatever.

It is suggested that the fireman learn to notice the draft gage, just as he observes the steam gage; it will indicate the need of shaking grates, the presence of air holes in fire when they burn too low, etc.

It is recommended that the firing be done as rapidly as possible consistent with the proper spreading of the coal, so that the doors will be open as short a time as practicable; also when about to clean by the slice and draw method, all tools that are to be used should be provided right at hand before beginning to clean, and put away after the cleaning is finished, and the door shut.

Firemen will answer the emergency call bell by reporting at once to the engineer.

If a fire alarm catches you with dirty fires, it is probably best to shake grates, or clean at once, and to do so as quickly as possible, even if you cannot take time to make the cleaning as complete as usual.

It is requested that the firemen, so far as is consistent with their other duties, shall keep the fire room, coal shed, etc., in a neat and tidy condition; this also applies to the toilet room, — always leave it in at least as good condition as you find it.

Firemen will sign their name to the recording steam charts on space that he is on duty.

For Boiler Room Helpers.

Follow our usual practice as to washing and cleaning boilers. As a general thing, about three weeks is a proper length of run; wash out all scale and mud, then pick off all scale that can be gotten at, and wash out again. In the case of the Stirling, the tubes may be turbined each cleaning, or the turbining may be omitted if conditions justify it.

Inspect boiler carefully for defective tubes, tubes needing rolling, bags in shell, or any leaks at any point. Also note the presence or absence of oil or grease in boiler and report to chief engineer. The tubes of tubular boilers should be brushed with wire brush when these boilers are cleaned.

Keep Settings Air Tight.

Boiler setting should be frequently inspected by the candle method for air leaks; fill any cracks or defects with a mixture of asbestos and fire clay.

Baffles.

The condition of baffles should be noted when Stirling boiler is cleaned and repairs made as needed.

Safety in Cleaning Boilers.

The non-return valves provide against return of steam to a boiler that is being cleaned; follow present practice *in seeing that all valves on the feed or blow-off lines that can communicate with any supply of steam or hot water*

are closed. Also, until some other method is provided, wire the wheels of such valves so the valves cannot be opened.

If the cleaning work takes you into a boiler alone, you should always notify the engineer on watch, or other responsible party, of the fact, and of which boiler you are working in.

Fusible Plugs.

When a boiler is being cleaned, the fusible plugs should be inspected and cleaned, both on the outside and inside; if it seems defective, it should be replaced by a new one.

LABORATORY.

The methods for carrying on the analyses in the Filtration plant shall, in so far as possible, conform to those prescribed in the Standard Methods of Water Analyses. The latest edition which has been published by the American Public Health Association, bears the date of 1920, and this should be followed until subsequent editions are made. Where daily tests are not carried on in conformity with those prescribed in the Standard Methods, special permission must be secured from the State Board of Health, permitting the use of these deviations.

The daily records as kept at the Filtration plant shall consist of the following determinations:

Chemical and Physical Tests.

Turbidity, raw water.
Alkalinity, raw and filtered water.
Chlorine, filtered water.
Total hardness, filtered water.
Temperature, filtered water.
Color, raw and filtered water.

Bacteriological Determinations.

Number of colonies grown on agar media at body temperature in raw and filtered water.

Tests for B. coli by noting gas formation in fermentation tubes, raw and filtered water. These to be confirmed where gas appears.

CHEMICAL AND PHYSICAL TESTS.

Turbidity. The turbidity shall, as a rule, be determined by means of the Jackson turbidimeter. The sample, as collected, shall be representative of that entering the plant. With the low-service pump in operation, and the alum solution fed under pressure, a representative sample can be col-

lected at the discharge of this pump, but back of the point where the alum is fed. When the alum solution is fed by gravity, the sample should be collected at the west side of the screen chamber by means of a small pump which has been provided for this purpose. As previously stated, care should be taken to collect, in each case, a representative sample, irrespective of the point at which it might be taken. When the river is rising, turbidity readings shall be taken every two hours.

Alkalinity. The determination of alkalinity shall be carried on in accordance with the instructions given on page 35 of the Standard Methods. If the raw water carries a large amount of matter in suspension, it is well to remove this before taking the alkalinity, in order that a better end point can be obtained.

Chlorine. The determination of chlorides in the water shall be carried on in accordance with the method outlined on page 41 of the Standard Methods of Water Analyses.

Total Hardness. In connection with the determination of total hardness in the filtered water, it is suggested that this be estimated by what is commonly known as the soda re-agent method, page 34 of Standard Methods, and not by the soap method as formerly used. The soap test is merely a record of the soap-destroying power of a water. The results are only approximate, and at best convey but little useful information. Where an analysis of the water has been made and the character well known, the soap test may be useful as a rapid means of determining any variations; but beyond this it does not furnish much real information.

In the tests for total hardness, the calcium and magnesium should each be determined separately and the results recorded. As a rapid method for determining the magnesium contents, the following is suggested:

Use 200 c.c. sample of filtered water; convert the carbonate hardness into sulphate hardness by the addition of N/10 or N/50 sulphuric acid, using methyl orange as an indicator. Place over bunsen burner and evaporate to 100 c.c. Add an excess of saturated solution of calcium hydrate or slaked lime. Immediately upon the addition of the hydrate of lime, the burner should be removed and the contents allowed to cool gradually. Filter and titrate the filtrate for excess alkalinity by means of standard sulphuric acid.

A sample of distilled water should be run as a blank at the time this determination is made. After boiling long enough to expel all free CO_2, equal amounts of the saturated lime solution are to be added to the filtered and distilled waters. The magnesium is then determined by differences.

The chief point to be observed in connection with the determination of magnesium is the greatly decreased solubility of calcium hydrate in the hot, over that when cool. As a guide in this respect, the following table has been prepared:

LIME SOLUBILITY.

32°	112 grains per gal.
40°	107 grains per gal.
50°	103 grains per gal.
60°	98 grains per gal.
70°	94 grains per gal.
80°	91 grains per gal.
90°	87 grains per gal.
100°	84 grains per gal.
140°	70 grains per gal.
180°	54 grains per gal.
212°	44 grains per gal.

The results obtained should be calculated as magnesium in terms of calcium carbonate. The calcium can then be estimated by taking the difference between the total hardness and the magnesium hardness. Although this means of determining the calcium is not absolutely correct, yet the error is very small and is sufficiently accurate for our determinations.

The determination of total hardness by means of the soap method can also be carried on if it is thought best as a general guide in the laboratory work. Results for total hardness are to be recorded in both grains per gallon and parts per million.

Chemicals for Softening. With the alkalinity, permanent hardness and magnesium hardness determined as p.p.m. in terms of $CaCO_3$ and the free carbon dioxide determined as CO_2, the chemicals required for softening can be estimated by applying the following factors:

For each p.p.m. of alkalinity as $CaCO_3$, it will require 0.0068 lb. of $Ca(OH)_2$ per 1 000 gal. of water treated.

For each p.p.m. of permanent hardness determined as $CaCO_3$, it will require 0.0113 lb. of Na_2CO_3 per 1 000 gal. treated.

For each p.p.m. of magnesium determined as $CaCO_3$, it will require 0.0068 lb. of $Ca(OH)_2$ per 1 000 gal. of water treated.

For each p.p.m. of free CO_2 determined as CO_2, it will require 0.0154 lb. of $Ca(OH)_2$ per 1 000 gal. of water treated.

The above factors have been determined upon the following strength of chemicals:

$Ca(OH)_2$ is assumed to contain 68 per cent. CaO. This is 90 per cent. of the theoretical strength.

Na_2CO_3 is assumed to be 98 per cent. pure.

Temperature. (Filtered water.) The temperature can be taken at the sampling sink, allowing the thermometer to stand in a freshly-drawn glass of water for at least three or four minutes.

Color. (Raw and filtered.) The color shall be determined by a comparison with glass disks, as recorded on page 10 of the Standard Methods.

Bacteriological Determinations.

In the bacteriological determinations, extreme care should be taken in getting a representative sample, also in seeing that all equipment is carefully sterilized, the media properly manufactured, and the technique employed conforms with the best practice. These points are covered in the Standard Methods and should be followed.

Colonies on Agar Media. The agar media shall be prepared in accordance with the instructions given on page 96 of the Standard Methods. With the approval of the State Board of Health, a dehydrated media prepared by the Digestive Ferment Company, of Detroit, Mich., can be used. At least one plate from the filtered and one plate from the river supply shall be made daily, and results recorded as number of colonies per cubic centimeter. In the event results in the laboratory are not up to the standard prescribed by the United States Public Health Service for water supplies on common carriers, viz., below 100 per c.c., it may be necessary to increase the number of plates made daily, and in addition take individual samples from each filter in service.

Tests for B. Coli. The tests for the presence of members of the B. coli group shall, in general, conform to that outlined on page 100 of the Standard Methods.* There have been two slight deviations from the method as given; namely, a reduction in the percentage of lactose in the endos media from 1 per cent. to ½ of 1 per cent., and increasing the amount of fuchsin. It has been found in connection with our laboratory work that a fuchsin solution, having a strength of approximately four times that given in the Standard Methods, gives us the best confirmatory results. These changes noted were made at the instigation of Mr. L. R. Taylor, water chemist and bacteriologist of the State Board of Health, after a two days' inspection had been made by him of the results obtained at our plant, July 9 and 10, 1919. This change was later confirmed by Mr. Taylor, in a letter written to Mr. Gwinn under date of November 4, 1919. The interpretation of results shall be made in accordance with the Standard Methods.

As a daily routine, it is suggested that five 10 c.c. samples of the filtered water and 1 c.c. sample of the raw water be planted in the lactose broth solution. As a guide in determining the sanitary qualities of the water supply, the results obtained should conform with those prescribed by the United States Public Health Service for water supplies furnished on common carriers; that is, out of five 10 c.c. samples planted in lactose broth, not more than one shall show positive confirmatory tests for B. coli.

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* The 1920 edition of the Standard Methods adopted the ½ of 1 per cent. lactose as the standard liquid media, and also increased the strength of the fuchsin solution to approximately that used in our laboratory.

Miscellaneous Tests.

The determination, as previously stated, shall be made daily. In addition to this, other determinations are to be made at less frequent intervals. These shall consist of —

Total residue and complete mineral analysis.
Free carbon dioxide.
Analysis of the filter alum as delivered.
Hardness in the boiler feed water.
Salts present in the boiler water, etc.

In addition to these, and especially during the summer months and at seasons of the year when micro-organic growths are most likely to be present in the water, microscopic examinations shall be made.

Total Residue and Mineral Analysis. The total residue on evaporation shall be determined in accordance with the method given on page 29 of the Standard Methods. Having obtained this, a complete mineral analysis should be made once each month, setting forth the total solids in solution, — silica, iron, aluminum, calcium, magnesium, sulphates, carbonates, chlorides, etc., — all as outlined on page 56 of the Standard Methods under the caption, " Mineral Analysis."

If a composite sample can be made, covering the entire month, by collecting 100 c.c. of water from each day's supply without a precipitation occurring of the soluble salts, during this period, this composite sample should be used in making the monthly mineral analysis. If a precipitation does occur, it is suggested that a composite sample be made covering a shorter period, this to be reduced to such length of time that no precipitation of the soluble salts will occur. The average, maximum and minimum river stage and chemicals fed shall be recorded, with the results of the mineral analysis.

Free Carbon Dioxide. The determination of free carbon dioxide shall be made at least once a month, and in accordance with the method given on page 40 of Standard Methods.

Filter Alum. As a general proposition, it is suggested that an analysis be made of each carload of alum delivered at the plant. This to determine in general the insoluble matter, aluminum oxide, ferric oxide, basicity ratio, and, if present, free sulphuric acid. The routine for such analysis is given on pages 77 and 78 of Standard Methods. A representative sample for such analysis can best be taken at the time the car is approximately half unloaded. In reporting results, car number, initial, and date of delivery should be included.

Feed Water. In the general instructions, under the caption, " Special for Chief Engineer," the hardness in the feed water as delivered to the boilers is to be determined weekly. Although it is suggested that the

soap method be used in connection with these analyses, more complete results could be obtained by determining the calcium and magnesium contents separately, as noted under Total Hardness. In addition to the hardness, observation should be made for the presence of oil. This could be determined quantitatively by noting the ether soluble matter, as given on page 69 of the Standard Methods.

Boiler Water. In testing the concentration of the different solutions in the boiler water, care should be taken in securing a representative sample. If this is drawn from the gage glass, the valve at the top of the glass should be closed in order to prevent steam from passing down into the sample. With the upper valve closed, the water should be drawn very gradually, in order that evaporation will not take place and thus increase the amount of the soluble salts present. It is the soluble salts in boiler waters that usually cause corrosion and pitting. In general, determinations should be made of the chlorides, sulphates, nitrates, carbonates, and silicates.

The metal magnesia offers the most deleterious action on iron, and especially if this occurs in the form of a chloride. It is, therefore, suggested that determinations, if possible, should be made to ascertain the manner in which the magnesium is combined with the different acids. The frequency and extent to which a boiler should be blown down should depend upon the concentration of the solution as shown by an analysis of this kind.

Microscopic Examinations. Micro-organisms are to be determined during the summer months, and at seasons of the year when these occur the character and amount of these different growths, to determine the manner in which the microscopic tests are to be made. The presence of these organisms is not to be looked upon as deleterious to health, yet, from an æsthetic standpoint, it is often the means of causing a great deal of dissatisfaction. At times, when such organisms are present, the determinations for nitrogen, dissolved oxygen, oxygen consumed, etc., might be of assistance in identifying the different genera. A full and complete record, with sketches and descriptions, should be recorded at the time these examinations are made. Whipple's *Microscopy of Water* and Ward and Whipple's *Fresh Water Biology* are to be used as a guide in these determinations.

FILTERMEN.

Filtermen will attend to their usual duties, as they have been instructed, and such special work as they may be given.

Filtermen, immediately upon coming on watch, shall inspect the condition of the alum tanks and note whether or not the proper feed is being maintained. Following this, they shall also inspect the basin when it is in use and see if the water is being properly treated and coagulated. If chlorine cell is in use, then inspect condition at the cell as soon as practicable after the other matters above have been attended to.

Filterman on watch will, soon after coming on, inspect recording water pressure gages for operation and time setting, and record same on daily half hourly report sheet. Filtermen will sign name to water-pressure charts in space that he is on duty, also on his daily report sheet.

The filtermen will usually be informed by the chief eningeer, by a suitable mark on the Chemical Feed chart, of the desired rate of alum feed and when the basin is not in use; the rate shall be made to correspond with the changes in speed of the Allis engine, by changing the alum feed plugs as may be necessary, noting the plug changes on daily report sheet. When the basin is in use, the rate of alum feed may be given, or it may be left to the judgment of the filterman; usually, in a changing river, it is not practicable to fix the alum rate, but must be changed as necessary to get a suitable coagulation. In the absence of definite instructions, or a changing river, try to use enough to get good water and, on the other hand, not to waste any alum. The practice of taking a glass of water as the water enters basin and setting it down while observing the basin, then looking at the glass again, is a valuable help in determining suitable coagulation.

If the river is changing when basin is off, the conditions should be watched closely and basin put on at about 50 to 60 turbidity.

Filtermen will keep filter plant and basin neat and clean; upon a fire alarm or call bell signal, they will report to the engineer promptly, and assist in any matter as the engineer may direct.

Any stoppage of alum or chlorine feed, when supposed to be in use, shall be noted on the filterman's report sheet with the time and duration of such stoppage. In addition to reading the gage on the alum tank at time of changing tank, record readings hourly.

Washing Filters. In starting to wash filters, the wash valve should be opened very slowly, taking about five minutes to get the full rate of wash. The length of time to be used in washing the filters will be given from time to time by the chief engineer, and shall remain the same until changed by definite instructions. Ordinarily, small filters should be washed about ten minutes and large filters about fifteen minutes.

Vertical Filters, No. 1 to No. 12, Inc. In washing the vertical filters, the wash valve (4 in.) is to be used wide open, as the proper rate of flow is maintained by other valves at each end of the wash line. After washing and filling, the proper rate of flow is obtained by opening the inlet valve four turns.

Horizontal Filters, No. 17 to No. 22, Inc. When washing these filters, open valve four or five turns, modifying this if necessary by observing speed of pumping engine, and maintain a uniform rate of washing. After washing and filling, regulate the rate of filtration by opening inlet valve five turns.

Horizontal Filters, No. 13 to No. 16, Inc. Same thing will apply, with the exception of using only three turns of wash valve.

After Washing Filters. Every time each filter is washed, the effluent should be turned into the sewer for about three minutes before turning into distribution system. Each time after washing filter (and before turning on) examine effluent within a few minutes after turning in, by filling pint Mason jars. These jars are to be kept for observation by chief engineer.

If, during the filter washing, any unusual behavior of any filter is noticed, indicating that something is wrong with it, the filter should be cut out of service and reported to the day man for examination.

Turbidity. The turbidity in the raw water is taken daily by the chemist in the laboratory at about 9.00 A.M. Where the condition of the water is not changing rapidly and the turbidity does not exceed 100, the observation made at that time can be used as a guide for feeding chemicals, and additional tests by the filtermen will not be necessary. When, however, the turbidity is in excess of 100, and especially if it is subject to rapid changes, each filterman is to make at least one determination for turbidity during his watch, and the results are to be recorded upon the filtermen's daily report sheets. During such periods, samples are to be collected at the following places:

(1) The raw water at the sink, if this is found to be representative.

(2) The north end of the settling basin, just east of the center partition wall and before passing to the west side of the settling basin; and

(3) The settled water at the sink after it has passed through the settling basin and before going to the filters.

The Jackson turbidimeter (candle) is to be used in taking turbidities where these exceed 25 p.p.m. If the turbidity falls below this amount, silica standards are to be used.

[Forms referred to in this paper are on file at the office of the New England Water Works Association.]

Discussion.

Mr. J. M. Diven.* What automatic sprinklers are referred to?

Mr. Gwinn. Those in our own plant. I should say that we did not care to burn down, and we don't carry very much insurance. We put automatic sprinklers all through the engine room and fire room, so that if we ever did have a fire we would have a chance to take care of it. All automatic sprinkler lines are supplied by a meter, with the exception of our own station. We have none on that.

Mr. William W. Brush.† How much interest do you find that the men take in the instructions? Do you find that they are interested in reading them, or is it necessary to continually remind them to enter their names in the spaces for the record?

* Superintendent, Water Works, Troy, N. Y.

† Deputy Chief Engineer, Bureau of Water Supply, New York.

MR. GWINN. I have not yet found it necessary to suggest to any of the men to read it. They know that the book is lying on the desk and that I am there nearly every day. So some time before the end of the month they will read it. They are doing that on our time, anyhow, and they are taking interest in their work. There is no doubt about that. We have a splendid force of men. We have a little box up there, by the way, marked for suggestions, so that if they have any suggestions they can put them in there; our relations are such that they do not have any hesitation in telling me what they want to tell me. They do not stand back and hesitate about it.

MR. BRUSH. Did you have any trouble during the war period — with men leaving you?

MR. GWINN. Oh, yes.

MR. BRUSH. What percentage?

MR. GWINN. Probably about twenty-five per cent., but we made up with older men who took the place of the younger men.

MR. J. S. DUNWOODY.* Another question regarding the advisability of furnishing men with reading matter. At our plant the chief engineer has been after me of late in regard to engineers and oilers spending too much time reading and allowing their work to drag, and especially on the night shifts. They bury their faces in the newspapers and forget that there is such a thing as a pump running in the plant. I rather hesitated to take away the papers from the engineering force of the station and have been supplying of late technical papers, such as *Power Plant Engineering*, *Machinery*, and various other periodicals that are published with reference to helping in their line of work. I do find that they read those magazines to a considerable extent, but I will say that I have come to the conclusion that newspapers should be excluded from the engine room. If Mr. Gwinn has had any definite experience along that line of reading, I should like to hear of it.

MR. GWINN. No, we furnish the daily papers for them, too. They want to keep posted on what is going on. We have the library of the American Correspondence School, the Power library and other books of the kind that the men might be interested in.

I want to make one statement before we go any further: Half the lies they tell on the Irish are not true. [*Laughter.*]

* Superintendent, Filtration, Erie, Pa.

EFFECT OF SMALL GATE OR VALVE IN LARGER PIPE LINE.

BY T. E. LALLY.*

[*Read September 8, 1920.*]

The loss of pressure caused by placing of a gate or valve of smaller diameter, with suitable reducer and increaser, in a pipe line of larger diameter, will be treated in this paper.

The writer has not found any extensive tests recorded on this subject, and such information as has been obtained may prove of value to engineers and superintendents having to do with the construction and maintenance of water systems. The statement has often been made that, if a smaller valve could be placed in the line without too much pressure loss, time could be saved in case of a break, and in Boston it is very hard — almost impossible — to put a line size gate in any of the feeder lines, because of the crowded condition of the underground street area by public-service equipment. Therefore it was thought desirable to determine, if possible, the actual loss due to a 12-in. gate with a reducer and an increaser in a 16-in. line.

The tests were made with a 12-in. gate placed between two 16 x 12-in. reducers in a 16-in. line. The gate and reducers were of the Boston Water Works standard. No selection was made and no extra care was taken with the castings. In fact, they were simply taken from stock and placed in the line. The test line was prepared by cutting in a 12-in. gate on the 30-in. low-pressure feeder line in Southampton Street west of the creek that is all that is left of the upper South Bay. This gate was extended as a 12-in. line to the street line, where it was brought to the surface by easy curves and continued on blocking, so that the bottom of the pipe was about 6 in. from the ground for 26 ft. The line was extended by putting in a 12 x 16 increaser, and then 16-in. pipe for a 23 ft., when a 16 x 12 reducer and a 12-in. gate with a 12 x 16 increaser were set. The pipe was then 16 in. for a 13½ ft., where a 16 x 12 reducer and a 12-in. gate were introduced. Then the line was continued with 12-in. pipe, 21 ft. to a curve and a special casting, with a flange, increasing to 14 in. internal diameter. To this casting was attached a bronze forebay, to which it was possible to attach nozzles from 8 in. on the forebay down to 2½ in.

The 16-in. pipe was bored, just outside each reducer, by ⅛-in. holes through the walls of the pipe 120 degrees apart, with one hole on the vertical diameter. These holes were then bored out part way through the pipe and tapped for ¼-in. iron pipe. Care was taken to remove any bur on

* Assistant Engineer, Boston Water Works.

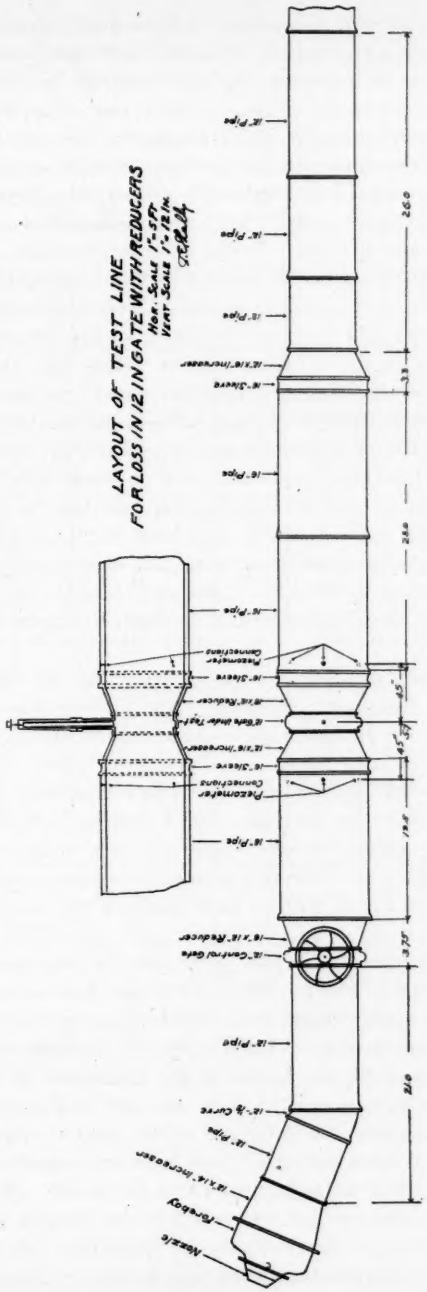

LAYOUT OF TEST LINE
FOR LOSS IN 12 IN GATE WITH REDUCERS
Hor. Scale 1"=5ft.
Vert. Scale 1"=12 in.
12" Pipe
12" Pipe
12" Pipe
12"x16" Increaser
16" Sleeve
16" Pipe
16" Pipe
Piezometer Connections
16" Sleeve
12"x16" Reducer
12" Gate Inlet
16" Sleeve
12"x16" Increaser
16" Sleeve
Piezometer Connections
16" Pipe
16"x12" Reducer
12" Control Gate
12" Pipe
12"-45° Curve
12" Pipe
12"x16" Increaser
Flanges
Nozzle
260
33
260
45°
45°
195
375
810

FIG. 1.

the interior of the pipe and to see that the holes were on radial lines and at right angles to the pipe. As will be noted, there was no chance for the ¼-in. pipe to enter the waterway and consequently no disturbance was caused by these connections. Pieces of ½-in. hose were attached to the lower ¼-in. pipes and both were brought together into a ¼-in. cross at the top holes. This cross was connected by ½-in. hose to a valve board with a number of ¼-in. valves on it, which were connected to a long U-tube with a suitably graduated scale. Both pipes were measured at these holes and found to be 16.01 and 16.03 in. It was not considered that this difference would have enough effect on the results to notice, and both pipes were considered of the same diameter and used as piezometer rings.

Carbon tetrachloride was used having a specific gravity of 1.60, to act as an indicator in the U-tube. Mercury might have been used, but, as the loss expected was small and the specific gravity of mercury is about 13.56, it will be seen that the carbon tetrachloride is twenty-one times more sensitive, and small differences in pressure give greater deflections in the U-tube. The tube and lines of hose were provided with blow-off cocks, and care was taken to lead the water upward to these so that air in the lines could be blown out. It will be seen from the sketch of the line that the difference in pressure, before entering the reducer and after leaving the increaser attached to the 12-in. gate, was caused to be shown in the U-tube, and by the use of a factor explained later the actual loss in pounds was arrived at.

The forebay and nozzles were kindly loaned by the engineers of the Factory Mutuals Insurance Company. The forebay was bored on the ends of two diameters at right angles to each other, and these holes were connected to gage fittings on the top by bronze tubes. The interior is of piston finish, as are the nozzles. The reducing portion of the forebay, from 14 to 8 in., was very gradual. The 8 reduces to 6 in. by a bolted fitting. The other reductions were made by screw nozzles, reducing one to another by inches, so there was a gradual reduction from the 14-in. forebay to the 2½-in. nozzle without any breaks in the interior wall of the waterway.

Flow was controlled by the last 12-in. gate, thereby keeping the gate under test always full of water. This control gate was operated by a hand wheel, and any pressure desired could be obtained in the forebay within the range of the nozzle used. From pressure readings on the forebay gage, after corrections for the height of the gage over the center of the nozzle, the discharge was calculated by the use of Freeman's formula. Readings on the gage and the difference on the U-tube were taken simultaneously, and from these readings it was possible to know the discharge and the loss for any flow up to the capacity of the nozzle. When the pressure in the forebay did not increase on the wider opening of the control gate, it was assumed that the capacity of the nozzle had been reached. The next larger nozzle was then used, and by the control gate the full

range of the discharge was run. In this way discharges from 700 g.p.m. to over 10 000 g.p.m. were obtained, and losses through the gate were measured. During all these runs the gate under test was always wide open, as the object aimed at was the losses in the gate and reducers, as if they were in a system supplying water, therefore the gate would be full open.

The available static pressure on the line at the gate being tested was 57 lb. It must not be assumed that the results here given are to be applied to every gate of this size. As the writer noted previously, this test

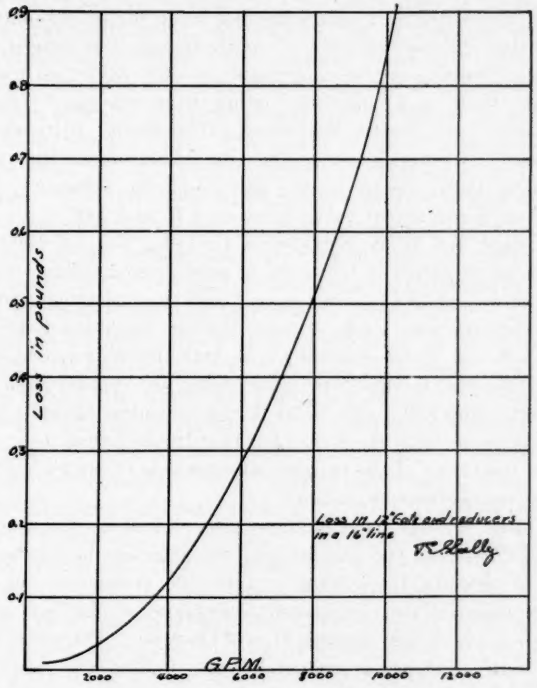


FIG. 2.

was on a standard gate of the Boston Water Works, and tests on gates of other design would probably give slightly different results. This gate is considered of good design. There are no obstructions in the waterway; the valve or plug and stem are out of the waterway when full open. A section through the gate on the line of flow is shown. As stated before, this was a stock gate, not one made for the test.

The results of the tests are plotted on cross-section paper. It will be seen that the curve does not follow the mathematical curve for losses. This rule, that "the loss in friction is as the square of the discharge," while near enough for practical purposes, does not obtain in these tests.

This caused a feeling that there was something wrong in the first test, and other tests were run, special care being taken to get the air all out of the lines and the connections tight in every way. The results agreed with the first, and the writer began to look for the reason.

It was found that the plotting of the curve, on a large scale for the losses, caused the difference to stand out, and while it was small it looked large on the plot, and being there caused further investigation. As far as the writer knows, losses due to such large flows through a gate of this size have never been recorded. Then, taking Freeman's paper "Hydraulics of Fire Streams," and analyzing some of the tabulated data, it was found that the loss did not vary as the square, but ranged from 1.775 to 1.92, and Freeman in the same paper (p. 338) says that his results do show "that there is a slight divergence from the law." Referring to Flinn, Weston, and Bogert Waterworks Handbook, 1916 edition, page 560, it reads: "Textbooks make the general statement that the friction head in pipes varies nearly as the square of the velocity. Researches indicate that this exponent varies between 1.75 and 2.00."

A. V. Saph and E. W. Schoder, A.T.S.C.E., Vol. 51, 1903, presented a paper on investigation of the losses in pipes from a velocity of a fraction of a foot per second to 44 ft. per second, and their plottings show different exponents for different kinds of pipe, but the exponent is evidently the same for each size, of the various kinds, with different velocities.

The velocities, in the 12-in. gate under test, varied from 1.3 ft. per second discharging 750 g.p.m. to 34 ft. per second at 12 000 g.p.m. With these references in view, the writer felt that the fact that the curve did not agree with the curve of the squares was not due to errors in the methods or the gage connections or readings.

The 14-in. forebay used in these tests slowed up the velocity of the water before entering the nozzles, and the gage on the forebay showed a very steady pressure, there being a noticeable absence of the vibrations, such as are shown in the piezometer tubes placed at the base of play pipes in flow tests made by him through lines of fire hose. The writer first figured the data with seven-place logarithms, and finding the results could be obtained by the slide rule to two places of decimals, used the rule for the greater part of the calculations. As we are dealing with hundredths of a pound loss, with a maximum of about a pound total loss, it did not seem necessary to resort to the longer method.

In calculating the discharge, from the pressures in the forebay, a correction was made for the elevation of the spring gage over the center of the nozzle. The discharge of 4 lb. and 64 lb. were calculated and plotted on a large sheet of logarithmatic tracing paper, making a straight line between, from which, with any pressure on the forebay with the size of nozzle discharging, the discharge was read off on the paper. This was done for each size of nozzle used, and greatly facilitated getting the data from which the curves were made.

In using carbon tetrachloride as an indicator, as the writer stated before, the deflection or difference in height of the tops of the column of fluid in the arms of the U-tube is about twenty-one times as great as it would be if mercury were used. This, however, introduces a condition that requires attention.

In a difference of 1 lb., using mercury, the measure of this in inches is about $2\frac{1}{3}$ in. With tetrachloride, being only 1.60 heavier than water, the difference ought to be about $17\frac{1}{4}$ in. as the weight of, or pressure due to, a head of water $27\frac{3}{4}$ in. in height is 1 lb. However, as the fluid drops in one arm it rises in the other, and water takes its place on the pressure side until a balance is obtained. Now, instead of reading the true difference in pressure, we have a column of water on one side greater in height than that on the other, or low-pressure arm, by the difference in height of the tops of the fluid in the tube. The weight of this column of water must be subtracted from the indicated difference in pressure to arrive at the true difference. The difference, when using mercury, is slightly over 2 in. for 1 lb. difference in pressure, and with mercury, under ordinary circumstances and unless dealing with large losses, may be neglected; but with such a height of water column, when using an indicator of such low specific gravity, a correction must be made for each difference in pressure.

The writer found that a factor could be obtained, by the use of which the true pressure could be arrived at with very little work. As the scale on the U-tube used by the writer was graduated for use of mercury, it was found that by multiplying the reading on the mercury scale for pounds and tenths of pounds by 0.044 the true difference in pressure for the specific gravity of 1.60 was obtained. This factor would change if the specific gravity of the indicating fluid was changed. With a tube that would give a difference of pressure of 30 lb. mercury, or about 6 ft. long, the tetrachloride would give a difference of pressure of about 1.32 lb. However, as a small loss was looked for, this indicator proved satisfactory.

The writer found that great care had to be exercised in the use of this indicator. The first runs were marred by irregularities in the readings, which were found to be caused by air in the rubber-hose connections. After having found the cause, great care was taken to keep the hose free from air, and the results began to agree one test with another. Tests were run on six different days, and the writer feels that the results given are very close to the actual conditions.

With a flow of 500 g.p.m. the loss was 0.01 lb.; at 1 000 g.p.m. it was scarcely larger; at 2 000 g.p.m. it was about 0.03 lb.; 4 000 g.p.m. showed about 0.12 lb.; 5 000 g.p.m. about 0.20 lb.; 6 000 g.p.m. gave 0.29 lb.; 8 000 g.p.m. about 0.51 lb.; 10 200 g.p.m. gave 0.92 lb.

These losses make a curve, when plotted to suitable scale, and show clearly that we may place this smaller size gate in our pipe lines and not lose over one pound pressure, with a discharge which I think would seldom be required even in a 16-in. line.

The writer thinks that, in addition to the information already given, it would not be out of place to add a little in another line, that he obtained while making these tests.

The indicator was drained out from the U-tube and mercury substituted. With the same set-up of the U-tube and a 5-in. nozzle on the forebay the control gate was opened full, getting a discharge of about 5 000 g.p.m. The writer then caused the gate under test to be started down, carefully noting the turns taken and watching the U-tube until the mercury showed one pound loss. It was found that the mercury gave 0.2 lb. loss with this discharge, with the gate open full as it had been when the flow tests were made. When the gate had been closed nine turns

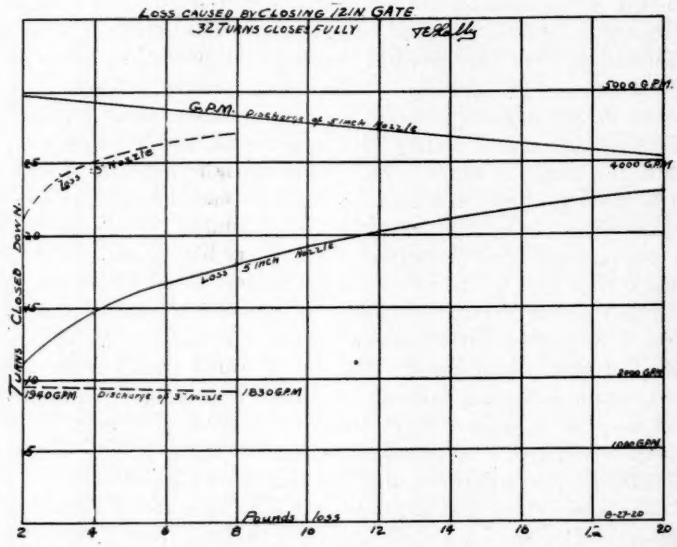


FIG. 3.

the loss was 1 lb.; 11¼ turns gave 2.0 lb.; 13½ gave 3.0 lb. loss; 14½ gave 4.0 lb. loss; 18 turns down gave 8.0 lb. loss; 21 turns gave 14.0 lb. loss; 22 turns gave 18.0 lb. loss; 22½ turns gave 20.0 lb. loss.

This was the limit of the mercury column, and no further losses were noted. This gate required 32 turns to close it fully. During this closing period the discharge fell from 5 000 g.p.m. to 4 050 g.p.m.

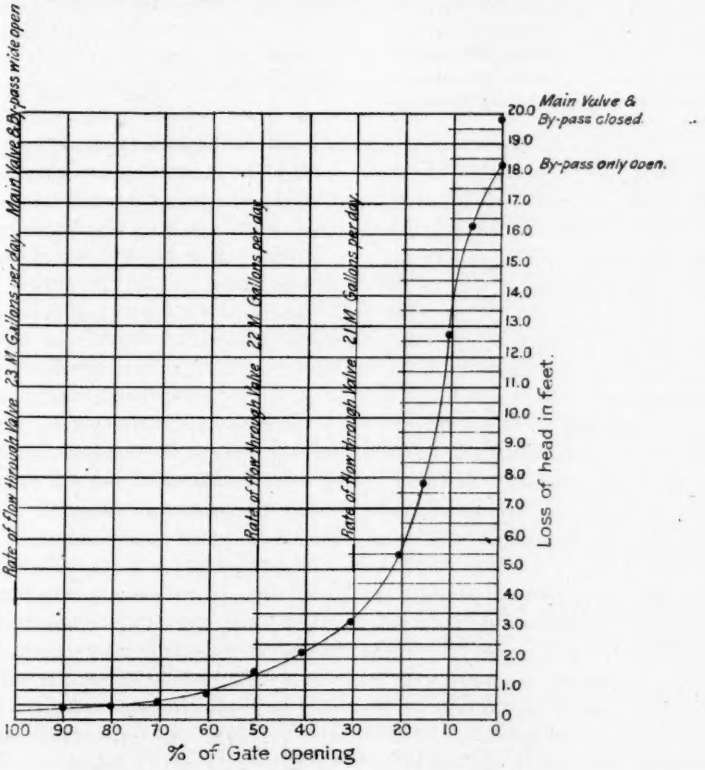
The test was then run, using a 3-in. nozzle to get a smaller discharge. The results would probably be more in line with the requirements of a small system. It was found that this gate was passing 1 940 g.p.m. full open with the 3-in. nozzle. The gate was closed down 20 turns before the pressure fell one pound, and the discharge was then 1 940 g.p.m. Twenty-

five turns gave a loss of 4.0 lb. with a discharge of 1 910 g.p.m.; 27 turns gave a loss of 8.0 lb. with a discharge of 1 830 g.p.m.

The gate was not closed down further, as it was considered that there was little likelihood that one would care to throttle a gate beyond this distance. The writer gives this data as a help to those who, for reasons you all know, would wish to keep water on a line and still do not want the gate wide open, in case anything should " let go " beyond.

DISCUSSION.

SAMUEL E. KILLAM.* In 1913, while hydraulic measurements were being made to determine the friction loss in the pipe lines on the Weston



Aqueduct Supply Mains on the Metropolitan water supply for Boston, an opportunity was afforded to observe the loss of head through a 36-in. valve on one of the mains. The total length between the piezometers was

* Superintendent, Metropolitan Water Works.

40 ft., which included a long and a short 60-in. to 36-in. reducer, a 60-in. manhole pipe, a 76-in. to 60-in. reducer, 5 ft. of 60-in. pipe, and 2 ft. of 76-in. pipe.

Gate Opening.	Loss of Head. (Ft. of Water.)
Gate and by-pass open	0.35
Closed 30 turns	0.39
Closed 60 turns	0.49
Closed 90 turns	0.63
Closed 120 turns	0.88
Closed 150 turns	1.65
Closed 180 turns	2.27
Closed 210 turns	3.28
Closed 240 turns	5.50
Closed 255 turns	7.80
Closed 270 turns	12.70
Closed 285 turns	16.30
Closed 303 turns	18.30
Gate and by-pass closed	19.80

These results are shown graphically on the diagram (page 309), from which it will be seen that the flow through the valve was at the rate of 23 million gallons per day when the test was started and, when the main valve was closed 50 per cent. of the area of the opening, the flow was at the rate of 22 million gallons per day, with a loss of head of only 1.65 ft. This loss increased rapidly as the valve was closed beyond this point.

W. C. HAWLEY.* Mr. President: Last winter a gentleman presented an excellent paper before the Engineers' Society of Western Pennsylvania, on mechanically operated valves, — that is, valves on which electric motors are mounted which will open or close the valve, the electric current being switched on to the motor from a distant point. He explained conditions in steam plants and the difficulty of getting to the valves on account of their inaccessibility, and how in case of the bursting of a steam main it was possible, by pushing a button, to start the motor and close the steam valve in a few seconds. He was enthusiastic on this proposition of the quick closing of a steam valve in case of an emergency in a power house, and we can readily appreciate the great value of his device, which is in successful operation in many power plants. He went on to show what a splendid thing it would be to have the valves in a large water-works distribution system equipped with motors, so that instead of taking half an hour or more it would only be necessary to push a button and the valve would be closed quickly, and the loss to property and contents by water flowing from the break would be materially reduced. I asked him if he had considered the possibility of further bursting of the mains by water hammer, due to the quick closing of the valve. He claimed that if necessary the valve could be closed at a rate of three inches per minute. My experience has been that in closing a valve, when the gate or gates are

* Engineer and General Superintendent, Pennsylvania Water Company.

nearly seated so as to materially obstruct the flow of water, it is necessary to continue closing the valve very slowly, — generally to take a turn or part of a turn on the wrench and then wait for a few seconds. Three inches per minute would cause a serious water hammer if there were any considerable pressure.

HENRY A. SYMONDS.* This reminds me of a curious case of reduction in the available cross-section of a pipe, and while the data are not as valuable as they might be had there been means for accurate observations, they are of some interest.

In a pipe line about four miles long, conveying water from an upper to a lower reservoir, supplying a population of about five thousand people and several manufacturing plants, there was occasion to lay a by-pass and pump through the by-pass for a time while a section of about 800 ft. was out of service.

One end of this pipe, which was 10-in., was plugged with an 8-in. plug in the spigot end of the 10-in. pipe.

By letting out the water in the section below this plugged end, and burning out the plug by fire under the pipe, a vacuum was created causing the plug to be drawn into the pipe line a considerable distance.

As it was during an intensive cold period in the winter, and the ground was frozen to a great depth, it was rather a frightful situation for those responsible for the water supply.

However, before orders could be given, the workmen had connected up the pipe and turned the water through the main section. There had been no margin above the demands of the town, and it seemed inevitable that there would be trouble in a day or two, when the lower reservoir was depleted.

To the writer's surprise there seemed to be no measurable reduction in the discharge of the pipe line and it seemed evident that there had been some mistake as to the plug being in the line.

After about a week, a warm spell occurred, and an effort was made to locate the plug, which was successful. The plug was slightly tilted, appeared to close the pipe line practically off, and had to be removed with a sledge hammer.

This instance seems to illustrate the fact that a marked contraction in the cross-section is possible under certain conditions without appreciable loss in volume of discharge.

C. W. SHERMAN.† It has been pretty generally known that, in the construction of the Boston Metropolitan pipe system, the main lines of which consist of 48-in. pipes, few 48-in. gates were used, practically all the valves being 36-in., and this is considered good practice. The paper that Mr. Lally has given us is of the greatest assistance in forming judgment as to how far the principle, which has been more or less accepted for large pipes, is applicable to smaller ones.

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* Consulting Engineer, Boston, Mass.

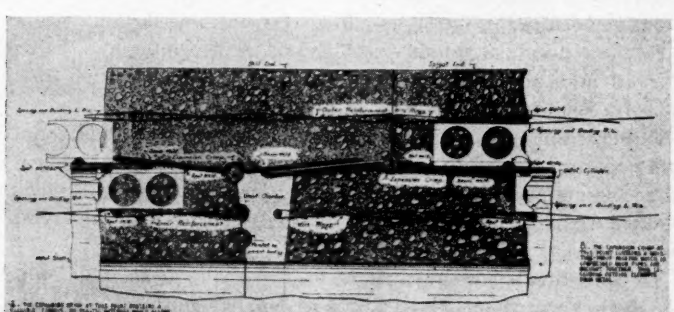
† Of Metcalf & Eddy, Consulting Engineers, Boston, Mass.

A NEW REINFORCED CONCRETE PIPE.

GEORGE C. BARTRAM.*

[*Read September 9, 1920*]

One of the most important questions that comes up for consideration by the members of this Association is the possibility of securing an ideal pipe line. The various qualities of an ideal line are, of course, dependent on the purposes for which and the conditions under which it is to be used. Under all conditions and for all purposes the pipe line must have the strength necessary to carry the pressure required, and should be leakproof, delivering at the outlet all of the water taken in at the inlet, and should have as low a coefficient of friction as possible. The line should not be subject to structural deterioration, nor should its carrying capacity decrease with age.



SECTION OF WALL OF PIPE

A. (Lower left-hand corner.) The expansion crimp at this point contains a flexible, fibrous, or plastic material which allows movement of crimp at this point.

B. (Lower right-hand corner.) The expansion crimp at this point contains a moisture-proof packing which is compressed when pipes are brought together, thus excluding outside elements from metal.

The defects and the merits in all of the systems now in use are well known. I propose to present to you the results of a series of extended investigations and experiments to develop a pipe line, especially for high-pressures, that will come as near to the ideal as seems possible. In my investigation I have kept in view the following points:

First, the method of construction must produce a line of sufficient strength to stand any pressure that may be required.

* President, United Concrete Pipe Company.

Second, the line must also be designed to the least amount of resistance to flow, and be so constructed as to maintain this low resistance.

Third, the line must have the minimum loss through leakage. The ideal line, you will readily understand, will show no leakage.

Fourth, length of life and maintenance cost.

Fifth, initial cost.

Naturally the first consideration is the material of which the line is to be constructed. From this point of view concrete is the only material which over centuries has shown the required unquestionable durability. It has also been proved by actual tests on constructed work that the coefficient of friction in a properly constructed concrete line is less than in any other form.

The question, therefore, arises, Is it possible to construct a line, based on the use of concrete as the principal material, which shall meet all of the other requirements set forth for an ideal line for both high and low pressure? How must the concrete line be given the necessary strength, and if constructed in sections how are the several sections to be combined into a unit line with the least possible obstruction to the flow of the water and the least leakage?

Taking the above points into consideration and looking over the field of what had been accomplished, we realized that the type of construction used on a great many miles of pipe line throughout New England, namely, the sheet-metal tube encased in concrete had proved its worth, and if this type of construction could be developed and designed so as to be utilized in larger sizes and a proper joint be made between the pipe sections, this would come nearer fulfilling the above requirements than any other type of pipe line that has been constructed. With this information it was a question of how to best use the principle involved in this structure that had already proved its possibilities. There is no necessity for me to go into details in this type of structure, as it has been used for so many years, principally in New England; so I will proceed to tell you how we propose to use this principle.

The thin sheet metal embedded in the concrete in small-diameter pipes would not require any means for mechanically bonding this concrete to the inside and outside faces of the sheet metal, as the thickness of the concrete casing and the metal are great enough to properly support the strain in these small sizes. To utilize this idea in larger pipes it becomes necessary to, in some way, form a mechanical bond that will cause the internal and external shells and the enclosed metal sheet to work in unison. This we accomplish by constructing a pipe built as follows:

In order to have an impervious pipe section of sufficient strength, in our design we use the necessary reinforcement, first with an impervious sheet-metal cylinder of such thickness as may be determined, and such additional reinforcement as may be required in the form of wire mesh or bars. The metal cylinder is constructed of sheet metal electrically welded,

so as to form an imperforate pipe, to the inside and outside faces of which we weld longitudinal perforated strips of metal. These strips not only act in the capacity of locking the reinforcement to the sheet-metal pipe, but also act as spacers to keep this reinforcement in the proper place. To the ends of the imperforate cylinder we weld sheet-metal rings, so formed as to take care of any contraction and expansion that may occur after the line is completed. These two rings are built into the pipe extending beyond the body of the pipe on the outside of the spigot and inside of the bell. When laid they form a lap joint on a bevel. This joint is electrically welded either from the inside of the pipe or the outside, as conditions may require.

This reinforced cylinder is then placed in the mold and the concrete poured, completing a pipe section. After seasoning, the pipe is laid in the trench and the metal joints are electrically welded. After the welding the open spaces are filled with concrete.

When the line is completed we have a continuous unbroken pipe line with the necessary contraction and expansion elements therein. So long as the line maintains its integrity there can be no leaks, as there is a continuous impervious metal cylinder without joints from intake to outlet. As the metal cylinder is thoroughly embedded in concrete it is protected from the action of the elements, and the only portion of the line subject to elemental action is concrete.

We believe that a line constructed as set forth will come nearer filling the requirements of an ideal pipe line than any that has ever been either used or offered.

In the construction of a low-pressure line it will be unnecessary to use the imperforate cylinder for the entire length of the line. By using a metal joint for uniting the several concrete sections, a line can be constructed to comply with all low-pressure requirements at a considerably lower cost.

TRENCHING-MACHINE EXPERIENCES IN THE CITY OF WORCESTER.

GEORGE W. BATCHELDER.*

[*September 10, 1920.*]

At the annual convention of the New England Water Works Association in 1917, held in the city of Hartford, a paper was presented which told the story of the use of the trenching machine up to that time.

In order to fully cover the subject up to the present time it will be necessary to repeat some points in the original paper.

The machine is a Model O, purchased of the Austin Drainage Excavator Company in 1913, at a cost of $7 000 less 5 per cent.

It is operated by steam, and was selected in preference to the gasoline machine because of the belief that there would be less trouble in securing operators who could handle a steam machine.

It has buckets of 18 in., 24 in., 30 in., and 36 in. width, and in each case the cut made is 6 in. wider because the teeth project 3 in. on each side.

As stated in the previous paper, trenches can be cut much wider than the buckets by barring down the material on each side of and in advance of the buckets.

The ordinary depth to which the machine cuts for water pipe in Worcester is 5 ft. This, of course, can be made more or less, with a range from 0 to 12 ft.

Best results are not obtained at the extreme depth because the boom runs so nearly vertical that the buckets spill much of the material before it reaches the conveyor belt.

Cuts have been made for a 48-in. pipe line with excellent results.

The machine has developed no weakness though it has been used in very hard digging.

It has done all of the trenching practicable in Worcester streets, and has been rented to municipalities and contractors in Hartford, Conn.; Quincy, Mass.; Dartmouth, Mass.; and Auburn, Mass., where it is now in operation.

Given a straight run in localities free from obstructions the machine is at its best and has cut hundreds of feet of trench in a day.

For use in the installation of new water or sewer systems in any soil except rock, it will go ahead so fast that the problem is to keep the pipe laid within hailing distance.

Examples of its work are shown in these records.

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* Water Commissioner, Worcester, Mass.

HARTFORD, CONN., 1917.

June 26, New Park Ave., 155 ft. long, 36 in. wide, 5 ft. deep, 5 hours.
June 27, New Park Ave., 200 ft. long, 36 in. wide, 5 ft. deep, 6 hours.
July 6, New Park Ave., 220 ft. long, 36 in. wide, 5 ft. deep, 7 hours.
July 19, New Park Ave., 320 ft. long, 36 in. wide, 5 ft. deep, 8 hours.
July 24, Quaker Lane, 408 ft. long, 24 in. wide, 5 ft. deep, 8 hours.

AUBURN, MASS., 1920.

Aug. 18 — Very coarse gravel, 410 ft. long, 24 in. wide, 5 ft. deep, 8 hours.
Aug. 19 — Loam, hardpan, and gravel, 250 ft. long, 24 in. wide, 5 ft. deep, 5 hours.
Aug. 20 — Hardpan, clay, and sand, 380 ft. long, 24 in. wide, 5 ft. deep, 6½ hours.
Aug. 21 — Sand and fine gravel, 165 ft. long, 24 in. wide, 5 ft. deep, 3 hours.
Aug. 23 — Filled land, very rocky, 384 ft. long, 24 in. wide, 5 ft. deep, 6½ hours.
Aug. 24 — Coarse gravel and sand, 438 ft. long, 24 in. wide, 5 ft. deep, 8 hours.
Aug. 25 — Very rocky and wet, 445 ft. long, 24 in. wide, 5 ft. deep, 8½ hours.
Aug. 26 — Fine gravel and hardpan, 295 ft. long, 24 in. wide, 5 ft. deep, 5½ hours.
Aug. 27 — Gravel, clay, and hardpan, 472 ft. long, 24 in. wide, 5 ft. deep, 8 hours.
Aug. 28 — Filled land, rocky, 180 ft. long, 24 in. wide, 5 ft. deep, 3½ hours.

This total excavation amounts to 34 190 cu. yd.
The costs of this work are:

Operator	$88.00
Fireman	66.00
Freight	38.00
Coal	48.00
Oil, etc.	20.00
Repairs and depreciation	20.00
Ex. labor	50.00
Total	$330.00

Cost of excavation per cubic yard	9.65 cents
Cost of excavation per cubic yard, including rental price	17.2 cents
Cost of excavation per cubic yard, hand labor (estimated)	63 cents

In addition to the work done in Worcester the machine has brought in a revenue for rentals of $9 011.28, not including the job now going on at Auburn, Mass.

The total cost of replacements and repair parts since the machine was purchased has been $3 864.44.

The machine shows no unusual signs of wear, and is apparently good for many years of service.

DISCUSSION.

SECRETARY GIFFORD. What are the rental rates?

MR. GEORGE W. BATCHELDER. Twenty-five dollars per day.

SECRETARY GIFFORD. Did I understand that a machine costs $7 000 and you had returns of $9 000 on it?

MR. BATCHELDER. Yes.

SECRETARY GIFFORD. Isn't it about time to send that machine around to the Massachusetts fellow-members?

MR. BATCHELDER. I think that is a fine thing to do. We encourage people to call on us when they have need and our machine is not busy, and make a reasonable price to them to keep the machine going and to help the sister towns of our state.

MR. A. E. MARTIN.* I have prepared no paper in connection with the use of a trenching machine, for, as I advised Mr. Sherman when he asked me to do so, we have had a machine for so short a time that we have no statistics to prepare a paper on.

On account of the high cost of labor and the difficulty of procuring it, also its inefficiency, which is the last but perhaps not the least of the troubles, for two or three years past the Springfield Water Department has been contemplating the purchase of a trenching machine, and it finally developed this year that, having a few miles of pipe to lay in the outskirts of the city, a machine was purchased. We did not purchase so large a machine as the city of Worcester had, as our distances in traveling across the city are long and our bridges are not of sufficient strength, perhaps, to carry the weight. The machine we purchased is a model 24 Parsons Excavator, which is listed to cut a trench 26 in. wide. We did not expect that we could lay any pipe larger than 20 in. diameter, but as a matter of fact we have found that it would not be troublesome to lay a 24-in. or possibly even a 30.

Springfield, as perhaps most of you are aware, has a soil that is very easily worked. We have very little rock and no hardpan of any consequence, mostly sand digging, and in many cases firm enough to stand without bracing the sides of the trench. Practically the first work we did was to lay a 16-in. main, and by breaking down the bank, as has been already mentioned, we had no difficulty in laying with this small machine the 16-in. mains, making an average from 300 to 500 ft. per day with a small gang of 8 men, — not including the foreman, of course. We also purchased a backfiller, which I need not enlarge upon at the present time. It does its work very nicely, although it requires puddling to make it most effective, and sometimes it is hard work to get the water to it in the trench. We also, soon after laying this 16-in. main, removed an old 16-in. water main, and used the machine for doing it. We had about 2 700 ft. from one of our old ponds that was used to reinforce our Ludlow supply before we had our new system, and, as that main was earning us nothing and being of no value where it lay, we concluded to dig it up. With this gang of 8 men — which we finally succeeded in increasing to 12 (after we had raised wages to 67½ cents an hour) — we removed that 2 700 ft. in 20 actual working days. From the time we started to move our machine, taking the men from the previous job, was just four weeks to a day. We excavated the trench to the top of the pipe, as close to it as we could, then with

* Superintendent, Water Works, Springfield, Mass.

two men working along side of the pipe shoveling the dirt into the buckets, we excavated deep enough to get a chain under the pipe, then lifted it with a derrick.

It may be interesting to know that we melted about one half a joint by a kerosene torch; the pipe was then worked out with a derrick. We salvaged the lead, and the cost of removing that pipe, roughly, and getting the amount of lead that we salvaged, was about a dollar a foot. I have no figures on the number of cubic yards of excavation that we did, but the trench on the top was about 5½ or 6 ft. wide, and sloped at the bottom to 24 in., and an average of 6 ft. deep.

This one dollar per foot included distributing the pipe where we proposed to re-lay it, about half a mile distant, so that the pipe itself distributed on the new job stands the department at the rate of about a dollar per foot, which, as you know, is quite cheap for a 16-in. pipe at the present time.

Our last job which we finished up before I came here was the lowering of a 30-in. main. We started by working the machine on one side of the pipe far enough away so that it would not hit the bells, then breaking down the bank on the other side with bars, and throwing it into the buckets by hand.

Six men were employed in the trench with the machine. About 400 ft. of 30-in. main was lowered and backfilled in about four days. We left bars under each length of pipe and dug out the dirt between them, and those bars were removed by a man on each side of the pipe with a shovel, the pipe lowering itself without trouble or without a hitch. Fifteen inches was the most that we lowered it at any one place, grading from either end.

We are now laying an 8-in. pipe, and if it is interesting to any of you, and it should be pleasant to-morrow, and you care to see its operation, we should be very glad to have you come down to Springfield, and we will show you the machine at work. As we are working now, we are not breaking the sides down, the bank being firm enough to stand, and yesterday afternoon, after making the connection with the new pipe that this is lateral from, they excavated for and laid about 250 ft. of pipe.

We know that we are doing more work and must be doing it cheaper. I will not make that assertion very strong, for we have no certificate to prove it, but we *are* doing *more* work, and we feel that it is going to be a successful and profitable investment.

SECRETARY GIFFORD. Mr. Martin, I should like you to state the cost of the machine in normal operation, the motive power, and the number of men to operate.

MR. MARTIN. The machine is a gasoline machine, and it cost us, including some additions that we made to it, practically $7 800. One of the additions that I referred to was that we were afraid to leave the machine on the street without some care over night. And we had to pay the

watchman laborer's pay and employ him seven days a week. So that an average of $35 a week or more was paid for the watchman. We went to one of our manufacturers in town and had a man come to see if a wire netting could be built around it, and he designed and finally built a wire cage similar to the grill work in banking institutions, and applied it to the machine. Since we have put that on we have not employed the watchman, and this cage, all on, cost us somewhere between $350 and $400, and we consider it a very good investment. The machine itself cost $7 200 plus the freight, which was somewhere around $150. One man can operate it, but we have hired an assistant for him, and pay the regular operator 80 cents an hour, and the assistant 70 cents.

SECRETARY GIFFORD. Perhaps I did not make myself clear, — I meant the number of men for pipe laying.

MR. MARTIN. We started with 8 men, and that gang was later increased to 12. The gang of 12 men will keep the machine at work, with the backfiller to help.

MR. DAVID A. HEFFERNAN.* From the time the order was placed, how long did you have to wait for the delivery of the machine?

MR. MARTIN. It was ordered in February and it was received the latter part of March. I should like to add that our machine stood on the tracks three weeks after it was loaded before it was moved. There was an embargo on the railroads, and we did not get the machine as quickly as we ought, but it was in time for our work.

MR. GEO. F. MERRILL.† We have a machine at Greenfield, the same as Springfield, Model 24 Parsons. We also have a backfiller. We had considerable delay in getting our machine. It was two months and a half *on the road* before delivery, and I had the pleasure of a trip to Chicago, spending about ten days on the road, hurrying it up, before we got delivery.

In regard to the use of the machine, I find that it is a great labor-saver. It sets a pace for the gang, and everything moves right along according to the pace of the machine. It really takes the "short" out of "shortage" of labor. It is very difficult to get men enough to handle pipe lines and dig any amount of trench. We have been using the machine in sand, which I imagine is much like Mr. Martin's conditions in Springfield. The day before yesterday, with our machine, we dug and laid 480 ft. of 8-in. wood pipe, and with a gang of 10 men, — two men directly behind the machine to keep the banks sloped down in the trench, so that we had a 6-ft. trench with $5\frac{1}{4}$ or 6 ft. width on top. It would average better than three quarters of a yard of material to the foot. One other day it laid 460 ft. under similar conditions.

I find we have to organize a gang of men particularly for use with the machine. We have got to look ahead and find out if there are any obstacles which are going to delay the machine. We have to keep the pipe-

* Superintendent Water Works, Milton, Mass.
† Superintendent Water Works, Greenfield, Mass.

laying material well ahead, and there is no doubt but that it is a very great labor saver. We also have used this machine on stiff clay and soft clay. On very hard, stiff clay the machine dug 200 ft. in three hours. That was in material hard enough so that it required no bracing. It would stand without sloping back. In soft clay we found the machine would not mire on very soft ground. The caterpillar treads with which machine is equipped give bearing enough so that it would go anywhere that an ordinary load on a wagon could travel. The backfiller goes with the machine and requires one man to operate it and will fill about twice as much trench as the machine will excavate in a day. Of course it requires puddling or some method of getting the filling into place. It wouldn't be very suitable to use on a street where it was paved, except by use of considerable labor in tamping or puddling the trench.

I haven't run into any very coarse gravel yet. I have not found any material that the machine would not go through. Roots are no obstacle. It will cut off roots as big as your leg and go right along. I imagine that round bowlders, close together, would delay a machine considerably. If you can loosen them up, the machine will handle them, if they are not too large; but it might not in an instance of that kind be profitable. Any material that we have struck we get away with it in good shape.

MR. WILLIAM R. CONARD.* The experience we have had with trenching machines was during the war construction period. At Camp Dix there were five machines used. One Austin, one Parsons, and three Buckeyes. These machines were used alternately for the water-works construction and for the sewerage construction. I have no figures or knowledge of the amount of work done for the sewerage, but for the water works from August 10, when the work first started, until about the middle of October, we used on an average two machines. We were able to dig trench for laying about 85 000 ft. of 8- to 16-in. pipe. The best record made for the pipe laying was in laying the force main of 16-in. pipe, in which in one day of ten hours we excavated a trench of a little better than 1 200 ft. The average for the force main was about 800 ft. per day. The soil was, generally speaking, a sandy loam, which, of course, made the digging easy. There were no detail cost figures kept by the engineering department, because there was no time — it was too much of a rush job.

Afterward, at the May's Landing ordnance plant of the Bethlehem Loading Company, which I had under charge, we used a new Austin machine, and our average there was about 600 ft. of trench, the reason being that it was practically all sand, and about 90 per cent. wet work, so that we could not proceed as fast; and also the fact that in most places we had to have a stumping gang ahead of the machine to take out stumps. Considering the conditions at May's Landing, I think that the average shows very well for a trenching machine.

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* Inspecting Engineer, Burlington, N. J.

Later, when I want to Pittsburg for the Neville Island housing project, we were planning to use trenching machines, and were investigating, until the time of stopping work, on the various types of machines, the number to be used, and the probable cost. The soil at the site of the project, with the possible exception of eighteen to twenty inches of top soil, was of Pittsburg shale, and in our investigations of the various machines we figured that for part of the work we could use machines of the Austin or Parsons type, that we could not use the Buckeye type of machine, but that we could use to considerable advantage, for the shale, the Keystone machine, which can be made a combination of either excavator or trenching machine. The estimates of cost that were worked out at that time for a 5-ft. trench, as I recall them, ran about 65 cents per linear foot of excavation. That would have been for a 2-ft. trench, and the figures were compiled taking into consideration the type of excavating that it would be necessary to do. Of course, if there were considerable work, we should not have been able to excavate the full 5 ft., but should have been compelled to do considerable drilling and blasting after having gotten down a ways, and then go back and take out the material with the trenching machine, the nature of the soil making it possible to go back over the trench with a machine, which ordinarily would be impossible.

COÖPERATION IN USE OF EQUIPMENT.

Topical Discussion.

President Macksey. You will find on that program that you have charged me up to deliver an address which will not be inflicted upon you. Mr. Batchelder's paper and discussion thereof will give us a line as to where and how we may search for information relative to exchange of equipment.

Is it wise for small communities to buy expensive equipment, and saddle themselves with the expense of expert operators for same?

If we can find out how many cities and towns have shovels, trenchers, and other expensive equipment, and who are willing to rent them, and the prices at which they will rent, we can save money for our employers. I shall be glad to hear from any city or town that has such equipment and is willing to consider renting when it is not in use.

Mr. Wm. R. Conard.* Apropos of what Mr. Macksey says, the New England Water Works Association is for the use of the members of the Association, and therefore members should make the headquarters of the Association a clearing-house for just such matters as that. The members can indicate to the office what equipment they have, and record can be kept, and, if another member wishes to use some equipment, he can find out from the Secretary's office what equipment is available in stock and, by means of correspondence, whether it is available or not.

Vice-President Sherman. I should think that suggestion would be quite workable, and that the Executive Committee will probably arrange for a card index if members will notify what they have, if they are willing to lend. It would probably require some kind of a notification to the membership that such an information bureau was contemplated.

President Macksey. I move that the Executive Committee be requested to prepare a circular asking for information in relation to equipment used by cities and towns, and which is rentable, and that a circular asking for that information be sent out with a regular notice of the meetings.

Mr. Samuel H. Mackenzie.† I will second that motion, for I think it would be very beneficial, and I should like to benefit by it; and if the Executive Committee would take that up we should save quite a little time and expense.

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* Inspecting Engineer, Burlington, N. J.
† Engineer and Superintendent, Southington Water Works.

THE HOLYOKE WATER WORKS, AND ITS RAINFALL AND STREAM-FLOW MEASUREMENTS.

BY P. J. LUCEY.

[*September 7, 1920.*]

The Municipal Water Works of Holyoke was first established in 1872, to provide for the growing needs of a town of about 10 000 inhabitants inadequately served by a private company.

Since then the town has grown to be a city of 62 000 population, noted for the excellence of its water-power development and for being the center of the paper industry in Massachusetts, and the leading city in the United States in the production of fine writing paper.

According to the federal census of 1910, it ranks twelfth in the list of Massachusetts cities in population and tenth in the valuation of its manufactured products.

It is distinctly a manufacturing city, having many large and prosperous textile plants whose output is more important, even in Holyoke, than that of its 27 paper mills.

One of the finest masonry dams in the world, superior in its materials and perfect in its workmanship, 1 020 ft. long and 30 ft. high above the bed rock, together with a well-arranged system of distribution canals, diverts the Connecticut River, whose drainage area is 8 000 square miles, to the useful purposes of industry with a wheel development of about 30 000 h.p.

Steam power, supplementing the hydraulic development, requires in the course of a year approximately 600 000 tons of coal, and the total railroad freight tonnage of its raw and manufactured products exceeds that of any other city in New England, except Boston and Worcester.

The area included within its boundaries is about 23 square miles; the greatest extent easterly and westerly being about 5 miles, and northerly and southerly about $9\frac{1}{4}$ miles. The built-up portion of the city covers about one third of its whole area, the remainder being mountain-land and small farms.

The water supply of Holyoke is obtained from the mountain streams in the western part of the city, whose drainage areas are fully developed by storage reservoirs high enough above the city to provide satisfactory pressure by gravity, and an auxiliary supply, the head waters of the Manhan River in Southampton, at a still higher elevation, which is connected with the local reservoirs by a 20-in. cast-iron main. These local reservoirs

Engineer for Water Department, Holyoke, Mass.

are known as the Ashley, Whiting Street, and the High Service reservoirs, and their construction and development was in the period between the years 1872–1904.

The Ashley System.

The Ashley Reservoir is located in the southwesterly part of the city, about 3½ miles from the City Hall, and consists of two natural lakes, which were the first of the reservoirs to be developed and used in 1872, the overflow having been raised about 5 ft. since then. It also includes the Bray Reservoir, built in 1880 to provide a small additional storage.

The drainage area of the Ashley system, not including its water surface, is 2.58 square miles. The surface area is 286 acres, and the elevation of its spillway is 322 ft. above sea level, about 170 ft. higher than the principal business street. The available storage capacity above the intake pipe is 854 million gallons, with an additional storage below it of 660 million gallons, which is available by pumping. The development per square mile of drainage area without recourse to pumps is 282 million gallons.

Fifty-two per cent. of the land inside the watershed boundaries is owned by the department, and there are only two dwelling-houses with a population of three to the square mile.

Whiting Street System.

The Whiting Street system consists of two reservoirs in the northwestern part of the city, at the easterly foot of Mt. Tom.

The first reservoir was a small intake built in 1884, with a low masonry dam flooding about an acre, with a capacity of about 1½ million gallons. The elevation of the spillway is 358 ft.

The other reservoir is the storage reservoir built in 1888, with a masonry dam of rubble sandstone 1 773 ft. long, the maximum height being about 25 ft. The surface area of this reservoir is 114 acres; the elevation of the spillway is 390 ft.; and the capacity is 479 million gallons, all of which is available. The drainage area is 1.47 square miles, and the development is 326 million gallons to the square mile.

There are no dwellings on this drainage area, about one third of which is owned by the Water Department.

The Manhan System.

The Manhan source of supply was secured in 1896, when, owing to the growth of the city, the consumption of water exceeded the safe combined capacity of Ashley and Whiting Street systems.

The development of this source as proposed at the beginning of the work was to construct a small intake reservoir at the junction of the Manhan and Tucker brooks in Southampton, Mass., where the drainage area

is 13.02 square miles, and connect it with the Ashley Reservoir by a 20-in. cast-iron main. This development was to serve until such time as a storage reservoir would be required, which was estimated then to be about fourteen years.

Accordingly, in 1896 and 1897, what is called the Fomer Reservoir was constructed by building a gravel dam with a concrete core at the junction of these brooks, having a length of 900 ft. and a maximum height of 20 ft.

The surface area of this reservoir is about 10 acres, and its capacity is 17 million gallons. The spillway at the westerly end of the dam is 150 ft. long between concrete wing walls, and the elevation of its crest is 440 ft. and is 5 ft. below the top of the dam.

Fomer Pipe Line.

In 1897 and 1898 a 20-in. cast-iron pipe 56 112 ft. in length was laid, connecting this reservoir with the Ashley Reservoir, where it terminated in a masonry canal in which was built a weir 4 ft. in length, for the purpose of measuring the discharge.

The first measurements, taken in 1898, showed the discharging capacity of this main to be at the rate of 4 572 000 gal. per day. Since then the discharge is constantly growing less, it now being 3 728 000 gal. per day, a loss of about 18 per cent. in twenty-two years. In 1918 a pitometer measurement of the discharge gave the rate as 3 840 000 gal. per day, checking the weir measurement made at the same time within four tenths of one per cent.

High-Service Reservoir.

To provide for the residential section developing on the higher area of the city, an earth dam, with a concrete core, was built on the Ashley drainage area, forming the High-Service Reservoir, and the pipe line from the Fomer Reservoir to the Ashley Reservoir was extended to it.

As the drainage area of this reservoir is only 47/100 of a square mile the greater part of the water drawn from it comes from the Manhan source, for which it acts as a holding and distributing reservoir.

The length of this dam is approximately 500 ft., and its average height is 25 ft.

On the southerly side of the reservoir is a dike about 900 ft. long, whose maximum height is 15 ft.

This dike served as a spoil bank for the stripping from the reservoir basin, which was very thoroughly done, and in some places this dike is over 100 ft. wide. It was thought best, however, to build it with a core wall and to construct that part of the embankment on the water side of the core wall with selected material.

The surface area of this reservoir is 61 acres, and its capacity, all of which is available, is 354 million gallons.

The elevation of the spillway is 431.50 ft., and all the water passing over it discharges into the Ashley Reservoir.

There are no dwellings on this drainage area, — 53 per cent. of which is owned by the Water Department.

Construction work on this reservoir was begun in 1899 and completed in 1904, all the work being done by the department's own forces, at a cost of about $135 000, of which about $85 000 was provided from the yearly earnings of the department and the balance by a bond issue for ten years.

Although the difference in elevation between the spillway of this reservoir and the spillway of the Fomer Reservoir is only 8½ ft., and the long pipe line would give a comparatively small discharge, it was expected that it would be sufficient until the projected storage reservoir on the Manhan would be built, when the main could be extended up the Manhan Brook to a small intake whose elevation would be high enough above the High-Service Reservoir to discharge the required quantity into it.

The White Reservoir.

The White Reservoir is situated on the Manhan Brook, about two miles upstream from the Fomer Reservoir, and was constructed in 1911–12, to provide the storage necessary to keep the 20-in. pipe filled when the run-off of the streams was no longer sufficient to supply the requirements of the Ashley and High-Service reservoirs.

A concrete dam was designed by and built under the supervision of the city engineer, T. J. MacCarthy.

It is 360 ft. long with a maximum height of 48 ft. and holds 650 million gallons when filled to the elevation of its spillway, which is 715 ft.,— 275 ft. higher than the Fomer Reservoir to which the water is allowed to flow as required. Its surface area is 132 acres, and its drainage area, exclusive of water surfaces, is 3.8 square miles. The total cost of dam and reservoir was $150 000, for which serial bonds running for thirty years at four per cent. were issued.

The New Intake Dam.

The dry seasons, locally, of 1913 and 1914 demonstrated the fact that the time had arrived to increase the discharge of the Manhan water into the High-Service Reservoir, the draft from which had more than doubled since it was first put in operation.

Consequently, in 1915 a 20-in. cast-iron main was laid up the Manhan Brook to the site of a proposed intake reservoir.

A concrete dam 12 ft. high and 147 ft. long, including a spillway of 80 ft., was finished in 1917, at a cost of about $18 000, the work being done by the department's own forces.

Summary of Sources of Supply.

A summary of the sources of supply shows that the total drainage area of land surfaces contributing to the reservoirs is 17.52 square miles; the area of the water surfaces of all the reservoirs is 93/100 of a square mile, and the total storage capacity is 2 354 million gallons. The safe capacity of the present developments is estimated to be sufficient for a city of 70 000, on the basis of present consumption, and when the Manhan drainage area is fully developed it is estimated that the sources of supply will provide for a city of about 110 000 population.

Distribution.

The distribution system is divided into the Low- and the High-Service districts, so-called not on account of the difference in pressures but to represent the lower and higher areas in the city which they serve.

The Low-Service District includes practically all the manufacturing and commercial users of water and has a residential population of 48 265, while the High-Service is entirely a residential district in the western part of the city and has a population of 13 425.

The Low-Service District is supplied by the Ashley Reservoir and the Whiting Street Reservoir; the High-Service District usually by the High-Service Reservoir alone, although occasionally a part of this district is supplied by the Whiting Street Reservoir.

Supply Mains.

The supply mains from Ashley Reservoir are a 24-in. cast-iron main, about 17 000 ft. long, laid from the gatehouse at the northeasterly corner of the reservoir to the center of the principal mercantile district, and a 16-in. main laid directly beside it for about 8 000 ft., where it is cross-connected with the 24-in. cast-iron main. There is also a 12-in. main taken off the 24-in. about 600 ft. from the reservoir, connecting with the distribution system at the extreme southerly part of the city.

The supply main from the Whiting Street Reservoir to the low-service distribution system is about 14 000 ft. long. It is a compound pipe of 20-in., 16-in., and 12-in. diameters, having a carrying capacity a little better than that of a 14-in. main.

The supply main from the High-Service Reservoir to the High-Service District is about 15 000 ft. long and is 20 in. in diameter for about 7 000 ft. from the reservoir, reducing to 16 in. for the remaining 8 000 ft. The capacity of all the supply mains is about 22 million gallons per day.

The mains inside the distribution system are all cast iron and total about 75 miles, ranging from 4 in. to 24 in. in diameter.

The secondary feeders are 10 in., 12 in., and 16 in., and the distributors are generally 6 in. and 8 in.

The 4-in. mains are in many cases paralleled by mains of larger size and do not directly supply hydrants.

The percentage of the various sizes of pipes in the distribution system are as follows: 4-in., 10 per cent.; 6-in., 38 per cent.; 8-in., 18 per cent.; the 10-in., 12 per cent.; 12-in., 12 per cent.; 16-in., 7 per cent.; and 24-in., 3 per cent.

Pressures.

The pressure in the Low-Service District varies from 25 lb. minimum to 105 lb. maximum, the average being 77 lb.

In the principal business part of the city the range is from 64 lb. to 80 lb.; and in the High-Service District from 66 lb. to 111 lb., the average being 81 lb.

The average pressure for the whole of the city is taken as 79 lb.

Hydrants.

There are 779 hydrants in public use, and 282 private hydrants in mill yards which are connected with and supplied from the city mains.

There are also 52 fire pumps in the mills which pump water from the canals, and the connections between these pumps and the water department's mains are all equipped with check valves and stop gates.

In the matter of fire protection Holyoke ranks well with the underwriters, being one of the few cities in New England which enjoys the lowest rates for insurance, and the water department is graded by the National Board of Underwriters as a city of the first class, having a total deficiency of only one hundred and forty-five points out of a possible seventeen hundred.

Consumption.

The consumption is measured by two Venturi and two Premier meters on the main feeders from the reservoirs.

The average daily consumption for 1919 was 6 664 000 gal., or 108 gal. per day per capita.

The consumption for the largest day was at the rate of 135 gal. per day per capita, and for the lowest day it was 86 gal. per day per capita.

The average daily consumption per capita for the largest week was 122 gallons, and for the smallest week it was 99 gal.

The classification and quantity of water used in gallons per day was as follows, viz.:

Domestic, metered	3.3 gal.
Public, metered (schools, engine houses, etc.)	3.7 gal.
Commercial, metered	10.0 gal.
Manufactured, metered	19.0 gal.
Total metered water sold	36.0 gal.
Water sold by fixture rate and unaccounted for	72.0 gal.
Totals	108.00 gal.

Service Pipes.

The service pipes are installed by the department at the expense of the consumer. The department makes the tap and lays the pipe to the inside of the cellar. Since the early part of the present year the rule of the department is that for taps on mains laid before 1918 a charge is made for stock and time plus a fixed sum from $10.00 upward, according to the size of the tap; and for taps on mains laid since 1918 a charge of $1.00 per front-foot of premises is made in addition to the charge for stock and time.

None but department employees are allowed to make taps, lay service pipes, or operate curb cocks.

Nearly every variety of service pipe is in use in Holyoke, but services less than 2 in. are mainly either lead lined or galvanized, while services over 2 in. are all cast iron.

The total number of services is 4 871, of which 10 per cent. are metered.

Rainfall and Run-Off on Manhan Drainage Area.

When the Manhan drainage area was taken as a source of water supply there was, of course, no records of its rainfall and run-off, and the computations of its probable yield were based on the flow of streams in other localities, particularly that of the Sudbury River.

In the summer of 1896 weirs were built on both the Manhan and Tucker brooks, just above the flowage line of the proposed new intake reservoir, and a rainfall station was established at a point just below the site of the proposed dam.

The weirs were of the standard rectangular type, with sharp crests and end contractions built so there would be no velocity of approach at time of ordinary flow.

Measurements were made twice daily, and more frequently in rainy weather, with a hook gage on both of these weirs, until the construction of the White Dam on the Manhan Brook in 1912. Since then no computations of the flow of this brook have been made.

Stream flow in the records reduced to a square-mile basis are for the combined flow of the two streams from 1897 to 1910 inclusive, and for the Tucker Brook alone since then.

The records of rainfall and stream flow for the dry years 1899 and 1908–09–10–11 were given in the report of the committee on yields of watersheds, and some of the information given there is repeated at this time.

The drainage area of the Manhan stream was 7.25 square miles, and was measured by a weir 10 ft. in length; the drainage area of the Tucker Brook is 5.75 square miles and the weir is a permanent concrete one whose crest is 6 ft. in length.

The drainage areas of both streams are similar in character, being rather mountainous with steep slopes. The soil is generally gravelly, and

about three quarters of the total area is wooded. There are no water surfaces except about a couple of hundred acres of undrained swamps.

The elevation ranges from 440 at its lower end to 1 550 at its upper end, about 6 miles northerly; the average elevation being about 950 ft.

Only about 3 per cent. of the land is under cultivation, the policy of the water department in buying land for the sanitary protection of the water having reduced the number of farms and inhabitants so that the population now is only about five to the square mile, and the real estate holdings of the department are about 25 per cent. of the total area.

Rainfall.

The rainfall is measured with a standard United States Weather Bureau gage, 8 in. in diameter, whose top is about 12 in. above the ground, and the measurements have all been made by the same observer.

The rainfall that has been received at this station from 1897 to 1919, both inclusive, is recorded in the following series of tables, and a comparison is made with that received on the Nashua River drainage area whose records cover exactly the same period of time and are widely known and accepted as standard.

The mean annual rainfall for the period of twenty-three years is 47.91 in., which is about 6 7/10 per cent. greater than the mean of the Nashua for the same period.

The maximum year was 59.41 in. in 1897, which is 24 per cent. greater than the mean; and the minimum year was 38.29 in. in 1899, 20 per cent. less than the mean.

The highest average for two successive years is 23 per cent. greater than the mean, and the lowest average of two successive years is 16 per cent. less than the mean.

The highest average for three successive years is 18 per cent. greater than the mean, and the lowest average of three successive years, 1917, 1918, and 1919, the last years of the period, is 12 per cent. less than the mean.

The greatest variation found in any one year between the annual rainfall on the Manhan and Nashua areas was in 1910, a year of low rainfall generally throughout Massachusetts, when the rainfall on the Manhan was 23 per cent. greater than that on the Nashua.

It also exceeded the amount received at Amherst by 29 per cent.; the amount at the Springfield Water Works station at Little River by 32 per cent.; and at our High-Service Station by 27 per cent., illustrating the well-established fact that rainfall may differ widely at stations not very far apart.

The rainfall received at the Granville station of the Westfield Water Works about 15 miles southerly, was only 10 per cent. less than the Manhan, and the high rainfall for the year was evidently local to those two areas.

It might be interesting at this point to state that although there were twelve of the twenty-three years when more rainfall was received on the Manhan, there were only ten years when the run-off was greater.

The variation in the annual rainfall from the minimum to the maximum is about the same on the Manhan as on the Nashua, the difference on the Manhan being 21.12 in., and on the Nashua 20.07 in.

The records show that the mean rainfall is quite evenly distributed throughout the year, and that the spring months although more favorable for the collection of surplus water are not the months of greatest rainfall.

The three consecutive months of highest rainfall are July, August, and September, and the amount received in the last six months of the year exceeds that in the first six.

November, which averages the month of lowest rainfall, with 3.32 in., is the second lowest month on the Nashua, with an average of 3.39 in.

In the series of twenty-three years, there were three years when November was the lowest month in the year, but there was no year when November was the wettest or next to the wettest month in the year.

The least rainfall received in any November was 1.00 in., but there are five years when the rainfall of other months was lower than that.

The wettest November was 6.59 in. in 1907, which amount was exceeded in some year by every one of the other months at least once, and by some of the months several times.

August averages the wettest month in the series, with 4.58 in., and is likewise the wettest month in the Nashua records, with 4.14 in.

On the Manhan it is found to be the wettest month in only one of the twenty-three years, but in no year in the series was it the month of lowest rainfall, and it ranked generally among the wettest months.

October presents more extremes than any other month, being the wettest month in four and the driest month in five of the twenty-three years.

The maximum rainfall received in any one month was 14.33 in. in June, 1903, and the minimum was .15 in. in March, 1915, a month notable all over Massachusetts for its deficiency in rainfall.

The average number of days in a year when the rainfall received was greater than .01 of an inch is one hundred and seven. The maximum number was one hundred twenty-one in 1916, and the minimum eighty-five in 1899.

The number of days when the rainfall was 1 in. or more ranged from twenty in 1901 to seven in the years 1911–1917, 1918.

The greatest number of days in a year when the rainfall was 2 in. or more was six; 3 in. or more, two; and 4 in. or more, one. There was no rainfall for twenty-four hours which equaled 5 in.

The maximum rainfall in any one day was 4.35 in.

The maximum rainfall for one day in the years 1899 and 1913, both years of low rainfall, was 1.75 in.

The greatest number of consecutive days without rain ranged from nine in 1907 to thirty-three in 1912.

TABLE 1.

MONTHLY RAINFALL IN INCHES RECEIVED ON MANHAN DRAINAGE AREA OF THE HOLYOKE WATER WORKS FOR TWENTY-THREE YEARS, 1897–1919 INCLUSIVE.

	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.
January	4.29	5.765	3.045	3.59	2.11	3.32	1.88	3.60	4.75	2.64	2.92	3.41
February	2.89	4.47	3.36	10.28	0.78	4.66	5.30	2.61	1.72	2.43	1.62	4.84
March	3.27	2.49	6.87	5.54	6.29	6.38	5.57	4.43	3.69	4.45	1.96	3.44
April	2.41	4.195	1.92	1.885	10.98	4.45	3.63	6.87	2.70	5.37	2.49	3.19
May	4.05	6.16	1.31	4.44	9.87	2.08	0.89	4.22	0.99	5.45	3.77	7.19
June	7.16	4.165	2.43	1.78	1.96	2.85	14.33	6.65	2.99	3.34	4.54	1.70
July	13.96	3.955	5.075	2.49	2.59	5.75	3.80	3.01	5.96	6.51	2.85	4.40
August	6.32	7.275	1.94	3.91	6.15	4.63	7.815	5.07	5.54	2.59	1.73	4.10
September	1.235	3.35	5.01	2.11	4.76	5.34	2.385	4.73	8.89	2.99	11.58	1.85
October	1.25	7.405	1.31	3.42	4.77	6.99	3.915	3.56	2.94	2.80	6.70	2.62
November	6.01	5.92	3.16	4.31	1.54	1.62	1.70	1.00	1.86	3.01	6.59	1.02
December	6.57	3.73	2.86	3.27	4.79	7.46	6.28	2.96	4.16	3.66	4.91	2.91
Total	59.415	58.88	38.29	47.025	56.59	55.53	57.495	48.71	46.19	45.24	51.66	40.67

	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	Mean.
January	4.33	7.97	2.08	3.65	3.61	3.21	6.605	1.81	4.57	3.81	2.30	3.71
February	6.41	6.88	1.905	3.12	2.32	5.65	5.575	6.44	2.36	1.85	3.25	3.94
March	5.295	1.60	4.195	5.39	5.78	4.32	0.15	2.83	4.19	1.58	6.13	4.17
April	6.45	5.36	2.62	3.26	3.95	5.13	3.97	4.44	2.24	2.90	2.54	4.04
May	4.00	3.58	0.84	4.60	5.19	4.005	2.27	3.24	3.40	2.86	8.38	4.03
June	3.12	3.70	4.06	0.80	0.67	2.01	2.43	5.89	5.23	4.30	1.75	3.82
July	1.16	1.67	4 43	2.43	1.88	3.18	8.96	5.42	1.84	2.88	4.66	4.30
August	4.70	4.48	6.71	4.96	2.37	3.20	9.82	2.06	3.07	3.84	3.00	4.58
September	4.36	3.07	4.55	3.375	3.44	0.185	2.08	8.04	0.72	6.67	4.02	4.12
October	1.32	0.72	8.84	5.79	6.77	2.03	2.01	1.55	9.37	1.43	2.56	3.92
November	2.34	5.59	2.58	4.24	3.74	3.32	3.41	3.79	1.03	2.93	5.75	3.32
December	3.64	1.87	2.98	4.70	3.06	3.14	5.42	2.97	4.30	3.47	2.06	3.96
Total	47.125	46.49	45.79	46.315	42.78	39.38	52.70	48.48	42.32	38.52	46.40	47.91

Average yearly rainfall, 47.91 in.
Maximum yearly rainfall, 59.415 in. in 1897, — 24 per cent. greater than the average.
Minimum yearly rainfall, 38.29 in. in 1899, — 20 per cent. less than the average.
Maximum average of two successive years, 59.15 in., 1897–1898, 23 per cent. greater than the average.
Minimum average of two successive years, 40.42 in., 1917–1918, — 16 per cent. less than the average.
Maximum average of three successive years, 56.54 in., 1901–1902–1903, — 18 per cent. greater than the average.
Minimum average of three successive years, 42.41 in., 1917–1918–1919, — 11 per cent. less than the average.

TABLE 2.

MONTHLY RAINFALL RECEIVED ON MANHAN DRAINAGE AREA, 1897–1919 INCLUSIVE. MONTHS IN ORDER OF DRYNESS.

Order of Dryness.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.
1.....	1.235	2.49	1.31	1.78	0.78	1.62	0.89	1.00	0.99	2.43	1.62	1.02
2.....	1.25	3.35	1.31	1.885	1.54	2.08	1.70	2.61	1.72	2.59	1.73	1.70
3.....	2.41	3.73	1.92	2.11	1.96	2.85	1.88	2.96	1.86	2.64	1.96	1.85
4.....	2.89	3.955	1.94	2.49	2.11	3.32	2.385	3.01	2.70	2.80	2.49	2.62
5.....	3.27	4.165	2.43	3.27	2.59	4.45	3.63	3.56	2.94	2.99	2.85	2.91
6.....	4.05	4.195	2.86	3.42	4.76	4.63	3.80	3.60	2.99	3.01	2.92	3.19
7.....	4.29	4.47	3.045	3.59	4.77	4.66	3.915	4.22	3.69	3.34	3.77	3.41
8.....	6.01	5.765	3.16	3.91	4.79	5.34	5.30	4.43	4.16	3.66	4.54	3.44
9.....	6.32	5.92	3.36	4.31	6.15	5.75	5.57	4.73	4.75	4.45	4.91	4.10
10.....	6.57	6.16	5.01	4.44	6.29	6.38	6.28	5.07	5.54	5.37	6.59	4.40
11.....	7.16	7.275	5.075	5.54	9.87	6.99	7.815	6.65	5.96	5.45	6.70	4.84
12.....	13.96	7.405	6.87	10.28	10.98	7.46	14.33	6.87	8.89	6.51	11.58	7.19
Total.....	59.415	58.88	38.29	47.025	56.59	55.53	57.495	48.71	46.19	45.24	51.66	40.67

Order of Dryness.	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	Total.	Average.
1.....	1.16	0.72	0.84	0.80	0.67	0.185	0.15	1.55	0.72	1.43	1.75	27.155	1.18
2.....	1.32	1.60	1.905	2.43	1.88	2.01	2.01	1.81	1.03	1.58	2.06	43.085	1.87
3.....	2.34	1.67	2.08	3.12	2.32	2.03	2.08	2.06	1.84	1.85	2.30	51.82	2.25
4.....	3.12	1.87	2.58	3.26	2.37	3.14	2.27	2.83	2.24	2.86	2.54	61.79	2.69
5.....	3.64	3.07	2.62	3.375	3.06	3.18	2.43	2.97	2.36	2.88	2.56	71.20	3.10
6.....	4.00	3.58	2.98	3.65	3.44	3.20	3.41	3.24	3.07	2.90	3.00	79.895	3.47
7.....	4.33	3.70	4.06	4.24	3.61	3.21	3.97	3.79	3.40	2.93	3.25	87.66	3.81
8.....	4.36	4.48	4.195	4.60	3.74	3.32	5.42	4.44	4.19	3.47	4.02	100.74	4.38
9.....	4.70	5.36	4.43	4.70	3.95	4.005	5.575	5.42	4.30	3.81	4.66	111.23	4.83
10.....	5.295	5.59	4.55	4.96	5.19	4.32	6.605	5.89	4.57	3.84	5.75	124.66	5.42
11.....	6.41	6.88	6.71	5.39	5.78	5.13	8.96	6.44	5.23	4.30	6.13	146.685	6.38
12.....	6.45	7.97	8.84	5.79	6.77	5.65	9.82	8.04	9.37	6.67	8.38	196.075	8.53
Totla....	47.125	46.49	45.79	46.315	42.78	39.38	52.70	48.48	42.32	38.52	46.40	1 101.995	47.91

Average monthly for twenty-three years, 3.99 in.
Average of 1st driest month, 1.18 in., — 70 per cent. less than mean.
Average of 12th driest month, 8.53 in., — 114 per cent. greater than mean.

TABLE 3.

MONTHLY RAINFALL RECEIVED ON MANHAN DRAINAGE AREA, 1897–1919. CALENDAR MONTHS IN ORDER OF DRYNESS.

Driest.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.	Average.
1.....	1.81	0.78	0.15	1.885	0.84	0.67	1.16	1.73	0.185	0.72	1.00	1.87	12.80	1.07
2.....	1.88	1.62	1.58	1.92	0.89	0.80	1.67	1.94	0.72	1.25	1.02	2.06	17.35	1.45
3.....	2.08	1.72	1.60	2.24	0.99	1.70	1.84	2.06	1.235	1.31	1.03	2.86	20.665	1.72
4.....	2.11	1.85	1.96	2.41	1.31	1.75	1.88	2.37	1.85	1.32	1.54	2.91	23.26	1.94
5.....	2.30	1.905	2.49	2.49	2.08	1.78	2.43	2.59	2.08	1.43	1.62	2.96	26.15	2.18
6.....	2.64	2.32	2.83	2.54	2.27	1.96	2.49	3.00	2.11	1.55	1.70	2.97	28.38	2.36
7.....	2.92	2.36	3.27	2.62	2.86	2.01	2.59	3.07	2.385	2.01	1.86	2.98	30.93	2.58
8.....	3.045	2.43	3.44	2.70	3.24	2.43	2.85	3.20	2.99	2.03	2.34	3.06	33.755	2.81
9.....	3.21	2.61	3.69	2.90	3.40	2.43	2.88	3.84	3.07	2.56	2.58	3.14	36.31	3.03
10.....	3.32	2.89	4.19	3.19	3.58	2.85	3.01	3.91	3.35	2.62	2.93	3.27	39.11	3.26
11.....	3.41	3.12	4.195	3.26	3.77	2.99	3.18	4.10	3.375	2.80	3.01	3.47	40.68	3.39
12.....	3.59	3.25	4.32	3.63	4.00	3.12	3.80	4.48	3.44	2.94	3.16	3.64	43.37	3.62
13.....	3.60	3.36	4.43	3.95	4.005	3.34	3.955	4.63	4.02	3.42	3.32	3.66	45.69	3.81
14.....	3.61	4.47	4.45	3.97	4.05	3.70	4.40	4.70	4.36	3.56	3.41	3.73	48.41	4.03
15.....	3.65	4.66	5.295	4.195	4.22	4.06	4.43	4.96	4.55	3.915	3.74	4.16	51.835	4.32
16.....	3.81	4.84	5.39	4.44	4.44	4.165	4.66	5.07	4.73	4.77	3.79	4.30	54.405	4.53
17.....	4.29	5.30	5.54	4.45	4.60	4.30	5.075	5.54	4.76	5.79	4.24	4.70	58.585	4.88
18.....	4.33	5.575	5.57	5.13	5.19	4.54	5.42	6.15	5.01	6.70	4.31	4.79	62.715	5.23
19.....	4.57	5.65	5.78	5.36	5.45	5.23	5.75	6.32	5.34	6.77	5.59	4.91	66.72	5.56
20.....	4.75	6.41	6.13	5.37	6.16	5.89	5.96	6.71	6.67	6.99	5.75	5.42	72.22	6.02
21.....	5.765	6.44	6.29	6.45	7.19	6.65	6.51	7.27	8.04	7.405	5.92	6.28	80.215	6.68
22.....	6.605	6.88	6.38	6.87	8.38	7.16	8.96	7.815	8.89	8.84	6.01	6.57	89.36	7.45
23.....	7.97	10.28	6.87	10.98	9.87	14.33	13.96	9.82	11.58	9.37	6.59	7.46	119.08	9.92
Total...	85.265	90.72	95.84	92.95	92.785	87.855	98.86	105.28	94.74	90.07	76.46	91.17	1 101.995	91.84
Average.	3.71	3.94	4.17	4.04	4.03	3.82	4.30	4.58	4.12	3.92	3.32	3.96	47.91	3.99

Mean monthly rainfall in twenty-three years, 3.99 in.
Rainfall for minimum month in twenty-three years, 0.15 in. in March, 1915.
Rainfall for maximum month in twenty-three years, 14.33 in. in June, 1903.
Average minimum calendar month is November, 3.32 in., — 17 per cent. less than mean average.
Average maximum calendar month is August, 4.58 in., — 15 per cent. greater than mean average.

TABLE 4.

DRIEST MEAN CONSECUTIVE MONTHS ON BASIS OF MANHAN RAINFALL, 1897–1919 INCLUSIVE.

Number of Consecutive Months.	Months.
1	November.
2	October and November.
3	September, October, November.
4	September—December, inclusive.
5	January—May, inclusive.
6	January—June, inclusive.
7	January—July, inclusive.
8	May—December, inclusive.
9	April—December, inclusive.
10	March—December, inclusive.
11	January—November, inclusive.
12	January—December, inclusive.

TABLE 5.

WETTEST MEAN CONSECUTIVE MONTHS ON BASIS OF MANHAN RAINFALL.

Number of Consecutive Months.	Months.
1	August.
2	July and August.
3	July, August, September.
4	July—October, inclusive.
5	April—August, inclusive.
6	March—August, inclusive.
7	February—August, inclusive.
8	February—September, inclusive.
9	February—October, inclusive.
10	January—October, inclusive.
11	February—December, inclusive.
12	January—December, inclusive.

RUN-OFF.

The yield of the Manhan drainage area given in the following tables is on the basis of one square mile of drainage area for the combined flow of the Manhan and Tucker brooks for the years 1897–1910, inclusive, and for one square mile of the Tucker Brook drainage area for the years 1911–19, inclusive.

For the fourteen years in which measurements were made on the two brooks, the total run-off of the Tucker exceeded that of the Manhan by 1 72/100 per cent.

TABLE 6.

YIELD OF MANHAN DRAINAGE AREA IN MILLION GALLONS PER SQUARE MILE PER MONTH, 1897–1919 INCLUSIVE.

	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.	1908.
January	19.996	42.706	45.558	14.632	9.427	72.593	45.650	21.931	70.264	35.609	40.389	55.130
February	29.976	31.287	20.242	116.188	5.526	36.275	58.163	19.198	16.473	20.473	15.304	42.432
March	75.626	117.074	50.634	86.821	68.637	133.004	125.716	82.160	91.445	50.621	72.137	76.647
April	62.604	68.798	147.789	59.537	195.499	69.759	82.601	142.516	77.161	90.108	44.405	58.344
May	36.206	75.718	25.605	47.154	123.050	30.858	17.026	53.967	19.631	42.992	38.181	88.163
June	48.868	37.087	7.427	11.220	30.469	11.893	81.556	63.556	11.342	18.722	29.277	22.107
July	141.361	10.694	11.300	4.617	8.970	17.309	35.303	19.916	14.597	16.048	9.307	13.027
August	59.251	20.773	3.967	5.251	19.409	15.575	45.624	15.589	7.200	9.675	2.934	10.645
September	17.477	8.940	8.937	2.357	25.893	22.885	19.452	25.451	54.176	5.597	46.035	5.107
October	9.838	39.352	6.124	5.659	23.773	51.197	42.091	29.019	20.675	21.085	69.656	7.386
November	33.651	57.376	13.016	29.791	15.735	27.422	28.965	18.512	18.635	22.127	94.035	7.592
December	71.322	47.097	13.991	29.476	81.938	56.264	48.431	19.804	30.031	23.187	49.920	8.522
Total	606.176	556.902	354.590	412.703	608.326	545.034	630.578	511.619	431.630	356.244	511.580	395.102
Average daily	1.661	1.526	0.971	1.131	1.667	1.493	1.728	1.398	1.183	0.976	1.402	1.080

	1909.	1910.	1911.	1912.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	Total.	Average Monthly.	Average Daily.
January.....	21.163	75.181	11.732	22.602	53.774	16.366	49.170	48.898	35.150	14.322	29.657	851.900	37.039	1.195
February.....	58.019	24.851	6.721	20.249	25.217	23.374	61.898	85.630	16.012	25.116	14.077	772.701	33.596	1.189
March.....	74.121	114.290	40.030	82.565	93.819	74.042	34.752	48.911	65.588	100.667	88.450	1 847.757	80.337	2.592
April.....	114.346	86.740	51.853	91.356	63.781	111.442	52.545	117.669	71.351	67.599	59.888	1 987.691	86.421	2.881
May.....	48.340	43.310	19.961	53.728	40.834	62.221	29.092	50.211	60.183	38.737	78.117	1 123.285	48.838	1.575
June.....	22.088	35.842	22.706	13.827	10.228	9.370	10.535	46.478	47.137	16.681	23.579	631.995	27.478	.916
July.....	3.894	4.147	14.076	4.677	3.418	9.013	65.448	20.765	13.189	8.473	10.865	460.414	20.018	.646
August.....	8.902	7.775	11.610	6.770	2.038	5.004	90.425	9.711	6.262	8.055	6.617	379.062	16.481	.532
September....	9.157	5.817	11.486	6.328	6.105	2.197	10.593	14.816	3.487	15.567	13.523	341.383	14.843	.495
October.....	5.557	4.067	65.275	22.470	22.865	3.679	9.596	11.660	30.216	8.538	10.283	520.061	22.611	.729
November....	5.797	13.551	43.897	30.528	19.947	7.181	43.508	24.300	16.918	15.633	38.895	627.012	27.261	.909
December.....	13.218	8.122	34.985	34.857	28.968	9.152	44.965	28.701	14.859	31.107	31.191	760.108	33.048	1.066
Total.....	384.602	423.693	334.332	389.957	370.994	333.041	502.527	507.750	380.353	350.496	405.142	10 303.370	37.331	
Average daily	1.054	1.161	0.916	1.065	1.016	0.912	1.377	1.387	1.042	0.960	1.110			1.227

TABLE 7.

MONTHLY YIELD OF THE MANHAN DRAINAGE AREA IN MILLION GALLONS PER SQUARE MILE. MONTHS IN ORDER OF DRYNESS, 1897–1919, INCLUSIVE.

Order of Dryness.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.
1.....	9.838	8.940	3.967	2.357	5.526	11.893	17.026	15.589
2.....	17.477	10.694	6.124	4.617	8.970	15.575	19.452	18.512
3.....	19.996	20.773	7.427	5.251	9.427	17.309	28.965	19.198
4.....	29.976	31.287	8.937	5.659	15.735	22.885	35.303	19.804
5.....	33.651	37.087	11.300	11.220	19.409	27.422	42.091	19.916
6.....	36.206	39.352	13.016	14.632	23.773	30.858	45.624	21.931
7.....	48.868	42.706	13.991	29.476	25.893	36.275	45.650	25.451
8.....	59.251	47.097	20.242	29.791	30.469	51.197	48.431	29.019
9.....	62.604	57.376	25.605	47.154	68.637	56.264	58.163	53.967
10.....	71.322	68.798	45.558	59.537	81.938	69.759	81.556	63 556
11.....	75.626	75.718	50.634	86.321	123.050	72.593	82.601	82.160
12.....	141.361	117.074	147.789	116.188	195.499	133.004	125.716	142.516
Total.....	606.176	556.902	354.590	412.703	608.326	545.034	630.578	511.619
Average.....	1.661	1.526	0.971	1.131	1.667	1.493	1.728	1.398

Order of Dryness.	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.
1	7.200	5.597	2.934	5.107	3.894	4.067	6.721	4.677
2	11.342	9.675	9.307	7.386	5.557	4.147	11.486	6.328
3	14.597	16.048	15.304	7.592	5.797	5.817	11.610	6.770
4	16.473	18.722	29.277	8.522	8.902	7.775	11.732	13.827
5	18.635	20.473	38.181	10.645	9.157	8.122	14.076	20.249
6	19.631	21.085	40.389	13.027	13.218	13.551	19.961	22.470
7	20.675	22.127	44.405	22.107	21.163	24.851	22.706	22.602
8	30.031	23.187	46.035	42.432	22.088	35.842	34.985	30.528
9	54.176	35.609	49.920	55.130	48.340	43.310	40.030	34.857
10	70.264	42.992	69.656	58.344	58.019	75.181	43.897	53.728
11	77.161	50.621	72.137	76.647	74.121	86.740	51.853	82.565
12	91.445	90.108	94.035	88.163	114.346	114.290	65.275	91.356
Total	431.630	356.244	511.580	395.102	384.802	423.693	334.332	389.957
Average daily	1.183	0.976	1.402	1.080	1.054	1.161	0.916	1.065

Order of Dryness.	1913.	1914.	1915.	1916.	1917.	1918.	1919	Average.
1	2.038	2.197	9.596	9.711	3.487	8.055	6.617	6.828
2	3.418	3.679	10.535	11.660	6.262	8.473	10.283	9.607
3	6.105	5.004	10.593	14.816	13.189	8.538	10.865	12.257
4	10.228	7.181	29.092	20.765	14.859	14.322	13.523	17.165
5	19.947	9.013	34.752	24.300	16.012	15.567	14.077	20.665
6	22.865	9.152	43.508	28.701	16.918	15.633	23.579	23.873
7	25.217	9.370	44.965	46.478	30.216	16.681	29.657	29.197
8	28.968	16.366	49.170	48.898	35.150	25.116	31.191	35.456
9	40.834	23.374	52.545	48.911	47.137	31.107	38.895	46.692
10	53.774	62.221	61.898	50.211	60.183	38.737	59.888	60.914
11	63.781	74.042	65.448	85.630	65.588	67.599	78.117	74.837
12	93.819	111.442	90.425	117.669	71.351	100.667	88.450	110.521
Total	370.994	333.041	502.527	507.750	380.353	350.496	405.142	447.973
Average daily	1.016	0.912	1.377	1.387	1.042	0.960	1.110	1.227

TABLE 8.

MONTHLY YIELD OF THE MANHAN DRAINAGE AREA IN MILLION GALLONS PER SQUARE MILE, CALENDAR MONTHS IN ORDER OF DRYNESS, 1897–1919, INCLUSIVE.

Order of Dryness.	January.	February.	March.	April.	May.	June.	July.
1	9.427	5.526	34.752	44.405	17.026	7.427	3.418
2	11.732	6.721	40.030	51.853	19.631	9.370	3.894
3	14.322	14.077	48.911	52.545	19.961	10.228	4.147
4	14.632	15.304	50.621	58.344	25.605	10.535	46.17
5	16.366	16.012	50.634	59.537	29.092	11.220	4.617
6	19.996	16.473	65.588	59.888	30.858	11.342	8.473
7	21.163	19.198	68.637	62.604	36.206	11.893	8.970
8	21.931	20.242	72.137	63.781	38.181	13.827	9.013
9	22.602	20.249	74.042	67.599	38.737	16.681	9.307
10	29.657	20.473	74.121	68.798	40.834	18.722	10.694
11	35.150	23.374	75.626	69.759	42.992	22.088	10.865
12	35.609	24.851	76.647	71.351	43.310	22.107	11.300
13	40.389	25.116	82.160	77.161	47.154	22.706	13.027
14	42.706	25.217	82.565	82.601	48.340	23.579	13.189
15	45.558	29.976	86.821	86.740	50.211	29.277	14.076
16	45.650	31.287	88.450	90.108	53.728	30.469	14.597
17	48.898	36.275	91.445	91.356	53.967	35.842	16.048
18	49.170	42.432	93.819	111.442	60.183	37.087	17.309
19	53.774	58.019	100.667	114.346	62.221	46.478	19.916
20	55.130	58.163	114.290	117.669	75.718	47.137	20.765
21	70.264	61.898	117.074	142.516	78.117	48.868	35.303
22	72.593	85.630	125.716	147.789	88.163	63.556	65.448
23	75.181	116.188	133.004	195.499	123.050	81.556	141.361
Total	851.900	772.701	1 847.757	1 987.691	123.285	631.995	460.414
Average	37.039	33.596	80.337	81.421	48.838	27.478	20.018
Average daily	1.195	1.192	2.592	2.881	1.575	0.916	0.646

Order of Dryness.	August.	September.	October.	November.	December.	Total.	Average.
1	2.038	2.197	3.679	5.797	8.122	143.814	11.151
2	2.934	2.357	4.067	7.181	8.522	168.292	14.024
3	3.967	3.487	5.557	7.592	9.152	193.946	16.104
4	5.004	5.107	5.659	13.016	13.218	221.662	18.472
5	5.251	5.597	6.124	13.551	13.991	232.052	19.588
6	6.617	5.817	7.386	15.633	14.859	262.930	21.911
7	6.262	6.105	8.538	15.735	19.804	285.115	23.760
8	6.770	6.328	9.596	16.918	23.187	301.911	25.160
9	7.200	8.937	9.838	18.512	28.701	322.405	26.561
10	7.775	8.940	10.283	18.635	28.968	337.900	28.158
11	8.055	9.157	11.660	19.947	29.476	358.149	29.847
12	8.902	10.593	20.675	22.127	30.031	377.503	31.458
13	9.675	11.486	21.085	24.300	31.107	405.366	33.780
14	9.711	13.523	22.470	27.422	31.191	422.514	35.210
15	10.645	14.816	22.865	28.965	34.857	454.807	38.234
16	11.610	15.567	23.773	29.791	34.985	470.015	39.168
17	15.575	17.477	29.019	30.528	44.965	511.395	42.216
18	15.589	19.452	30.216	33.651	47.097	557.447	46.454
19	19.409	22.885	39.352	38.895	48.431	624.393	52.033
20	20.773	25.451	42.091	43.508	49.920	670.615	55.885
21	45.624	25.893	51.197	43.897	56.264	776.915	64.743
22	59.251	46.035	65.275	57.376	71.322	948.154	79.013
23	90.425	54.176	69.656	94.035	81.938	1 256.069	104.622
Total	379.062	341.383	520.061	627.012	760.108	10 303.370	
Average	1.6481	14.843	22.611	27.261	33.048		
Average daily	0.532	0.475	0.729	0.909	1.066		1.227

TABLE 9.

Manhan Drainage Area.

Table showing per cent. of rainfall collected; rainfall in inches received; inches of rainfall collected, and the average daily run-off, per square mile, for each year, 1897–1919, inclusive.

Year.	Per Cent. of Rainfall Collected.	Yearly Rainfall Received.	Inches Collected.	Average Daily Yield, Mils. of Gal. per Sq. Mile.
1897	58.71	59.415	34.88	1.661
1898	54.42	58.88	32.04	1.526
1899	53.23	38.29	20.38	.971
1900	50.53	47.025	23.76	1.131
1901	61.86	56.59	35.01	1.667
1902	56.48	55.53	31.42	1.493
1903	63.11	57.495	36.29	1.728
1904	60.44	48.71	29.44	1.398
1905	53.77	46.19	24.84	1.183
1906	45.31	45.24	20.50	.976
1907	56.99	51.66	29.44	1.402
1908	55.91	40.67	22.74	1.080
1909	46.96	47.125	22.13	1.054
1910	52.44	46.49	24.38	1.161
1911	41.99	45.79	19.23	.916
1912	48.43	46.315	22.43	1.065
1913	50.04	42.78	21.41	1.016
1914	48.64	39.38	19.15	.912
1915	54.85	52.70	29.41	1.377
1916	60.27	48.48	28.91	1.387
1917	51.72	42.32	21.89	1.042
1918	52.36	38.52	20.17	.960
1919	50.24	46.40	23.31	1.110
Average	53.79	47.91	25.77	1.227

Maximum percentage collected in 1903, 63 per cent.
Minimum percentage collected in 1911, 42 per cent.
Maximum inches collected in 1903, 36.29.
Minimum inches collected in 1914, 19.15.

TABLE 10.

TABLE SHOWING THE MEAN MONTHLY RAINFALL RECEIVED AND COLLECTED. PERCENTAGE OF RAINFALL COLLECTED AND YIELD IN GALLONS PER DAY, PER SQUARE MILE, ON THE MANHAN DRAINAGE AREA, 1897–1919, INCLUSIVE.

Month.	Mean Rainfall Received.	Mean Rainfall Collected.	Mean Percentage of Rainfall Collected.	Mean Yield in Gallons per Day per Square Mile.
January	3.71	2.13	57.49	1 195 000
February	3.94	1.93	49.01	1 189 000
March	4.17	4.62	110.93	2 592 000
April	4.04	4.97	123.01	2 881 000
May	4.03	2.81	70.42	1 575 000
June	3.82	1.58	40.93	916 000
July	4.30	1.15	26.80	646 000
August	4.58	0.95	20.72	532 000
September	4.12	0.85	20.73	495 000
October	3.92	1.30	33.22	729 000
November	3.32	1.57	47.18	909 000
December	3.96	1.90	47.97	1 066 000
Totals and averages	47.91	25.77	53.79	1 227 000

TABLE 11.

DRIEST MEAN CONSECUTIVE MONTHS IN YEAR ON BASIS OF MANHAN RUN-OFF.

Number of Consecutive Months.	Months.	Average Daily Run-off in Gallons for the Period.
1	September.	495 000
2	August — September.	513 000
3	July — September, inclusive.	558 000
4	July — October, inclusive.	601 000
5	July — November, inclusive.	662 000
6	June — November, inclusive.	701 000
7	June — December, inclusive.	756 000
8	May — December.	859 000
9	April — December.	1 080 000
10	March — December.	1 233 000
11	February — December.	1 200 000
12	January — December.	1 227 000

TABLE 12.

COMPARISON OF THE MEAN ANNUAL RAINFALL AND RUN-OFF ON THE MANHAN DRAINAGE AREA FROM 1897 TO 1919, INCLUSIVE, WITH THAT OF THE NASHUA RIVER DRAINAGE AREA FOR THE SAME PERIOD.

	Manhan.	Nashua.	Percentage Manhan Greater than Nashua.
Mean annual rainfall, inches	47.91	44.87	6.7
Percentage rainfall collected	53.79	49.80	4.3
Inches of rainfall collected	25.77	22.345	15.4
Run-off lowest month — gallons daily	495 000	362 000	36.7
Run-off 2 lowest successive months	513 000	386 000	32.9
Run-off 3 lowest successive months	558 000	400 000	39.5
Run-off 4 lowest successive months	601 000	421 000	42.8
Run-off 5 lowest successive months	662 000	486 000	36.2
Run-off 6 lowest successive months	701 000	533 000	31.5
Run-off 7 lowest successive months	756 000	616 000	22.7
Run-off 8 lowest successive months	859 000	692 000	24.1
Run-off 9 lowest successive months	1 080 000	846 000	21.7
Run-off 10 lowest successive months	1 233 000	1 021 000	20.7
Run-off 11 lowest successive months	1 200 000	1 053 000	14.0
Run-off 12 lowest successive months	1 22 7000	1 063 000	15.4

TABLE 13.

TABLE SHOWING THE STORAGE REQUIRED TO MAKE AVAILABLE VARIOUS DRAFTS IN GALLLONS PER DAY PER SQUARE MILE OF WATERSHED, ALLOWING 6 PER CENT. FOR WATER SURFACES ON THE BASIS OF MANHAN RUN-OFF AND MAKING NO CORRECTION FOR THE DRY DAYS IN THE MONTHS PRECEDING AND FOLLOWING THE CRITICAL PERIOD.

Daily Draft.	Storage Required Gallons.	Period.
100 000	6 600 000	August — December, 1914.
200 000	17 300 000	June, 1914 — January, 1915.
300 000	32 600 000	June, 1914 — January, 1915.
400 000	54 100 000	June, 1914 — February, 1915.
500 000	75 500 000	May, 1914 — February, 1915.
600 000	96 900 000	May, 1914 — April, 1915.
700 000	117 900 000	May, 1914 — July, 1915.
800 000	151 100 000	June, 1910 — April, 1912.
900 000	198 400 000	June, 1910 — March, 1913.
1 000 000	248 600 000	June, 1910 — December, 1914.

TABLE 14.

TABLE SHOWING THE RUN-OFF OF THE MANHAN DRAINAGE AREA FOR DRIEST CONSECUTIVE MONTHS.

Number of Consecutive Months.	Average Run-off in Gallons per Day per Square Mile.	Number of Consecutive Months.	Average Run-off in Gallons per Day per Square Mile.
1	66 000	13	534 000
2	88 000	14	523 000
3	118 000	15	513 000
4	148 000	16	553 000
5	177 000	17	646 000
6	197 000	18	691 000
7	213 000	19	692 000
8	259 000	20	692 000
9	358 000	21	714 000
10	453 000	22	805 000
11	519 000	23	786 000
12	541 000	24	821 000

The mean annual flow for the whole of the period of twenty-three years is 1 227 000 gal. per day per square mile, which is 15 4/10 per cent. greater than the mean flow of the Nashua River for the same period.

The maximum run-off in any one year was 1 728 000 gal. per day in 1903, 41 per cent. more than the mean, and the minimum run-off was 912 000 gal. in 1914, 26 per cent. less than the mean.

In fourteen of the twenty-three years the run-off was less than the mean, and in every one of these years the rainfall for the year was less than the mean rainfall for the period. In the remaining nine years of the series in which the run-off was greater than the mean, the rainfall in every year was in excess of the mean rainfall for the period. The mean percentage of rainfall collected on the Manhan was 53.79 per cent., which is 4 4/10 per cent. more than the percentage of rainfall collected on the Nashua.

The table of mean monthly flow shows that the collection of water distributed through the different months in the year varies considerably from the distribution of mean rainfall throughout the year.

August, which averages the highest month in the year, in rainfall received, averages the second lowest month in the quantity of water collected, and is the month in which the minimum run-off occurred. July, which is second highest month in rainfall received, is the third lowest in run-off.

July, August, and September, the three months in which the highest rainfall was received, are the three months in which the least water was collected.

In the order in which the run-off is distributed throughout the different months, the Manhan corresponds very closely to the Nashua. In the matter of consecutive months, it is exactly the same. On the Nashua,

however, for the winter months, December, January, February, and March, the percentage of rainfall collected and the run-off both slightly exceeded that on the Manhan for the same period.

For the balance of the year the Manhan is higher both in run-off and percentage of rainfall collected, the run-off of the six driest months exceeding the six driest on the Nashua by about 31 per cent.

The storage required to make available various drafts agrees very closely in the higher drafts with the storage as given by the Report of the Committee on Yields of Watersheds in September, 1914.

The storage required for the lower drafts has been increased by the low flows subsequent to the making of the report by the committee.

The maximum run-off in one month occurred in April, 1901, with an average daily flow of 6 517 000 gal. per day, per square mile, which was almost one hundred times the minimum monthly flow in August, 1913.

The maximum daily run-off was 39 205 000 gal. on February 13, 1900; and the maximum flood discharge was on the same day at the rate of 183 cu. ft. per second, per square mile.

The rainfall for this month was 10.28 in. and included 4 storms greater than 1 in., the rainfall on day of maximum flood being 3.05 in.

Management.

The department is operated under a commission of three members, who serve without salary, one of whom is elected each year by the Board of Aldermen for the term of three years.

The commissioners select the officers and employees of the department, levy the rates, and collect and disburse the funds of the department through their own treasury, which is separate and distinct from the city treasury.

They are also, with the mayor, the trustees of the sinking fund established for the payment of the water department debt at maturity by annual sums set aside from the yearly receipts.

The department is self-supporting; in only one instance was it ever granted an appropriation raised by general taxation, and that was in the early days before the department finances were well established, when $10 000 was granted.

In 1901 this loan, together with interest at 4 per cent. for the whole of the period, was returned to the city treasurer.

Rates.

The present rates, which were established in 1909, provide for the sale of water by both the fixtures and the meter measurement methods.

Dwelling-houses, stores, and tenement houses generally are rated by the fixture; while mills, office buildings, and apartment houses of the first class are under the metered service.

The annual fixture rates are as follows, viz.:

For each family	$3.00
For each bathtub	2.00
For additional bathtub	1.33
For closet	2.40
For additional closet	1.60
For garden hose (limited use)	2.40
For rotary hose	9.60
For automobile	1.60
For washing machine	1.60

For stores a charge from $4.00 to $9.60 is made, varying according to the character of the business. Other established rates, such as the charges for horses, neat cattle, etc., yield such little revenue they hardly need to be considered.

Bills for service under the fixture rate are rendered quarterly, and a discount of 10 per cent. is allowed for payment in advance.

Metered water is charged at the flat rate of $5\frac{2}{3}$ cents per thousand gallons, the bills being rendered monthly and 10 per cent. discount allowed for prompt payment. A minimum yearly charge of $5.00 per apartment is established for all apartment houses on the metered service.

Meters are owned, installed, and repaired by the department, and the annual rental for their use is: $\frac{5}{8}$-in., $2.00; $\frac{3}{4}$-in., $2.00; 1-in., $3.00; $1\frac{1}{2}$-in. $6.00; 2-in., $16.00; 3-in., $24.00; 4-in., $50.00, and 6-in., $60.00.

Assuming that the unaccounted for water was 30 per cent. of the total quantity passed by the master meters in 1919, the cost to the consumer of water sold by meter measurement was $5\frac{1}{4}$ cents per thousand gallons; the cost to the consumer of water sold by fixture rate was 11 8/10 cents per thousand gallons, and the average cost to all the consumers was 8 3/10 cents per one thousand gallons.

The total cost, or book value, of the department at the close of the last fiscal year was $1 969 892.

The bonded debt was $441 000, and the amount in the sinking fund to meet that portion of the debt financed on the sinking fund method was $193 207, making the net debt of the department $247 793, or $12\frac{1}{2}$ per cent. of the total cost, and the net cost of the plant to the water-takers $1 722 009.

The gross receipts, from all sources, for the year 1919 were $168 804.83, equal to 8 6/10 per cent. of the total cost.

It would seem that an accusation of profiteering would fall flat against any corporation whose total receipts in 1919 were only 8 6/10 per cent. of its total investment.

Taxes.

The largest item of department expense after salaries and wages is the one generally called " payment of taxes " to the city of Holyoke. The payment called " taxes " by a municipal department into the city treasury

is an unusual thing, this being, so far as is known to the writer, the only department where such payment is made under legislative enactment, and the various municipal departments are required to pay for water used and for fire hydrants, the same as to a private water company.

This law was enacted in 1901, and as its provisions are self-explanatory it may be of interest to read them in full.

Section 2:

"The said Board of Water Commissioners is hereby authorized and directed to pay over to the treasurer of the said city in each year, on or before the 1st of November, from its net earnings, a percentage upon the total cost of the construction of said water works, as estimated in the annual reports of the said commissioners, which shall be the same as the percentage of taxation established for city, county, and state taxes in the city of Holyoke in that year. The treasurer is hereby authorized and directed to collect the said sum and pay over the same to the commissioners of the sinking fund for the payment of municipal bonds. In case the net earnings do not equal the said percentage, the whole net earnings shall be paid over as aforesaid. The amount so paid or collected shall be used toward the payment of municipal bonds, other than water bonds."

Section 3:

"The Board of Water Commissioners is hereby authorized and directed to collect payment from all municipal departments of the city of Holyoke except the Fire Department, for the water used by them, at the same rate which is paid by other consumers."

Section 4:

"The Board of Water Commissioners is also hereby authorized and directed to collect from the Fire Department an annual rental, not exceeding eight dollars ($8.00), for each public hydrant. This rental shall include the cost of all water used by the Fire Department for fire or other purposes, including the cost of furnishing and maintaining hydrants."

The total of all payments made by the water department to the city treasurer under these provisions is $422 556.26, and the amount received by the water department from the other municipal departments is $215-863.28, making the net cash contribution the water-takers have made for the benefit of the general taxpayer, $206 692.98.

A summary of the leading features of the Holyoke Water Works shows that its percentage of debt is small and that its present development is sufficient for many years to come; that its drainage areas when fully developed will provide for a city about twice its present size; that its supply is obtained from sources where the danger of pollution is slight and held in reservoirs large enough to provide long storage, and that the supply is delivered under a satisfactory pressure to the water-takers at rates which compare favorably with those in any city in this country.

Discussion.

Mr. Robert E. Horton.* I regret that more members of the Society who are particularly interested in matters of rainfall and run-off were not here to listen to Mr. Lucey's paper. He has pointed out some valuable records, and I am sure that members of the Society will receive with appreciation the paper that he so carefully prepared and presented, in print. I am sure we shall all find a great deal of valuable material and a great many ways in which the matter may be put to useful purposes.

Thirty years ago, when the records of the Manhan River were started, there were not, as I remember, more than a half dozen records that were reliable and generally available throughout the whole United States, and we can readily see under those conditions how valuable such a record becomes to us. The only way that that condition can be overcome is by the accumulation of such records. I know from experience that the keeping, day in and day out, of records of rainfall is a monotonous and arduous task, and I feel that the water department of the city of Holyoke is entitled to a great amount of credit for the excellent manner in which they have kept their records, and I might add in regard to other matters mentioned in this paper that I am forced to the conclusion from what Mr. Lucey has said that they have a most excellent water department.

There is one statement that interested me, and that is, the matter of charging for the water used. It has for a long time seemed to me that it was an entirely just and equitable proposition for the school and other city departments to pay to the water department the actual cost, or at the original rate, or on some basis for the water that they use.

Although that has been discussed here and there, Holyoke seems to be the only place where it is actually done. I should like to be in a position where I could some time say in answer to a municipal question, " If you would only follow the excellent example of Holyoke, some of your troubles would be done away with, because a large portion of the expense is being saddled on to the water department, and if the city departments pay their portion you might have money to put into your sinking fund to help pay for the future when you need an additional source of supply " ; and it would seem to me that a great deal of good would come about as the result of such a procedure.

I wish to ask one or two questions: First, as to measuring rainfall in the wintertime. Second, as to obtaining information as to taking water measurements, — whether there is any difference in taking at higher elevations than at the lower levels.

Mr. Lucey. Mr. President, we have no way of knowing just what the rainfall is at the upper end. On one or two occasions during the period we got water which showed that a storm had taken place at the upper end of the watershed and was not recorded at the lower. The snowfall

* Consulting Engineer, Albany, N. Y.

was measured in the usual way. We take a number of small measurements, and don't allow the can to fill up and lack attention.

MR. HUGH MCLEAN.* The question of taxation in Holyoke was a problem that bothered us for many years. The tremendous use of water for lavatories and schools and engine houses continued to grow, in spite of the care of our inspectors. The waste was enormous and the consumption was very high. I have always thought that the equitable and just way is for a water department to compel municipalities and their different departments to pay into the water department's treasury for all the water they use, and in return that should be credited as we pay into the city treasury what the average tax might be if a private corporation owned the water department. That is equity and justice. That tends to place the sale of water as nearly as possible on the cost-of-water basis. It has been in our mind to attain as nearly as possible perfection, and to establish the cost of water is only to make the consumers pay for the cost, and all of those who consume the water should pay for what they consume.

I think it is just to make a charge for everything that is used in new extensions. For instance, a farming suburb may be bought by a promoter, and he splits the land up into building lots which immediately increases the value of that land, merely from the fact that the water department and the gas and electric departments put their money in, and he sells all those lots for an enormous profit. We thought it perfectly just on applications for extensions like that to make them bear fifty per cent.

*Water Commissioner, Holyoke, Mass.

PROGRESS REPORT OF COMMITTEE ON ASSESSMENTS FOR MAIN PIPE EXTENSIONS.

MR. CALEB SAVILLE, CHAIRMAN.

[*September 8, 1920.*]

We have sent out something like three or four hundred inquiries to various parts of the United States. I will not attempt to read the replies, but just to show that we have not been lax in looking up this matter, there are two closely written, typewritten pages from private water companies, from whom we received reports and tabulated eleven pages of the same, on municipal supplies of various kinds. Some of the features — the salient features of these four fifths that might be called " primary conditions " — I will read.

Assessments for Main Pipe Extensions.

1. Common Method. — Guarantee of some stated amount annually, say 10 per cent. of the cost.

2. Duluth Method. — Eight per cent. of first cost of a 6-in. pipe, charged annually against abutting property for fifteen years on basis of 5 per cent. interest and 3 per cent. sinking fund, with 25 per cent. discount if payment is made in one installment. Against this charge is credited one half the water revenue paid by occupant of premises; vacant land pays full 8 per cent.

3. Washington (D. C.) Sanitary Suburban Commission. — Levies a benefit charge on all property in district abutting on the water mains. This benefit charge is to be paid annually during the life of the bonds out of the proceeds of which the construction work was done. Any property owner may extinguish the annual benefit charge by paying in cash an amount which, put at interest, 3½ per cent. annually, will yield an annuity equal to the annual assessment for the period for which the assessment is levied. The annual benefit charges become a first lien against the property on which they are assessed for a period of two years unless reduced to a charge according to law. The benefit charge is payable immediately upon being levied, with interest at 1 per cent. per month.

4. Pennsylvania Water Company Method (private company). — " Bonus Agreement." To pay interest, depreciation, and taxes on the cost of the extension and furnish water to consumer there must be an average return equivalent to 15 per cent. on the cost of the extension. The minimum rate by this company is $10 per year; $10 is 15 per cent. of

$66.67. On petition for extension, the entire cost is advanced by the petitioner and held by the water company without interest. Refund is made to original petitioners at the rate of $66.67 for each new consumer supplied by the extension.

5. Bristol, Conn. — This city, by amendment to the city charter passed by the General Assembly of 1915 and approved by the voters of Bristol, October 7, 1919, has the following authority for laying a lien against abutting property both for non-payment of water bills and for cost of water-pipe extension:

"All charges for water, including an amount guaranteed as an inducement to lay new street mains, with the cost of laying or replacing service pipes upon public or private property, shall be a lien upon the real estate where or for the benefit of which such charges are incurred. When the estimated income shall not amount to 10 per centum of the estimated cost of laying a water main on any highway or private way, the Board of Water Commissioners may assess against the real estate to be benefited by the laying of such a main the cost above the amount of which the income shall be 10 per centum and such assessment shall be a lien upon such real estate. At least five days' notice shall be given to the owner or owners of the real estate upon which the cost of such pipe mains may become a lien, of the proposed extension, and of when and where it will be acted upon by the said Board. When the owner of the property upon which an assessment has been paid shall connect with the water main, the assessment shall be refunded or as much thereof as the assured income shall be 10 per centum. The liens provided for in this section shall have the same legal status as the liens provided for in Section 26 of this charter, and shall not continue for a longer period than 60 days after invoice of the authorized charges has been rendered, unless, within said period, a certificate of such lien shall be lodged with the town clerk for record."

The only place where we found, so far, that the assessment is a lien upon property has been at Bristol, Conn., where there was an act passed by the legislature giving that authority.

That seems to be the logical method, and to appeal at first sight to people. "Why not make it a lien upon the property?" I should like to say in regard to that, that at one time I discussed the matter very considerably with Mr. Stearns, and I remember his saying at that time that theoretically it was good, but practically not to do it. There were certain practical conditions that in his experience he had found were not good. I stated that this was the only place we had found; I think there are some others, because it was called to my attention, not long ago, that the city of Chicago laid a water main, and the cost was made a lien upon the property. It was carried up to the courts and the courts decided against the payment, on the ground that the extension was not warranted by the development of the property. That, gentlemen, is as far as we have gone.

Discussion.

Mr. J. M. Diven.* I should like to ask the members of the committee if any consideration was taken of the size of the main, or if the assessment was made on some definite size; such as six or eight inch.

Mr. Saville. We found in many places that 6 in. seemed to be a nominal size. It seems proper that, rather than to assess the cost on the actual operation, it would be better to determine a general rate covering the average conditions, for one man might be so unfortunate as to live on a rocky hill, and his cost of installation might be two or three times as much as if he lived in a low country where the earth could be easily excavated.

Mr. Diven. The method that I have used for a private water company and a municipal plant for new developments only, is this: The owners of the property advance the money for laying the mains, this money to be returned to them when paying a fair return on the cost. I think we took about ten or twelve per cent. If the development failed, the city or water company was nothing out. The promoter had to stand the loss. The water company or the city did not have to put up money for speculation.

President Macksey. I would say on this line that in a small city where I was employed recently we were on the old original system where, if there were voters enough on the top of the hill far out in the country, we laid the water main. When the water department authorities grumbled at the cost thereof, and called attention to the fact that there would be no return, it was said: "A large pipe is not necessary. Put in a 1-in. All we want is a little water." And after it was decided to furnish water the question would come up: "Isn't Mr. So-and-So going to pay the same rate as the others?" "Surely he is"; and therefore he should have good service. That meant that he should have a larger pipe. Now, if you laid a 4-in. pipe, you would have very good service. If you are going to furnish water to a man at all, the least that you might do is to protect his house against fire, and also against the rapacity of the insurance agent, by putting a decent hydrant in front of his house. Sometimes officials in charge of the water department protested against being forced to go on in this way. But the mayor — a very practical and effective man — said, "You go ahead. I will make them sign an agreement that the rental shall be 10 per cent. on the cost of the installation."

In another small place where I was employed they have the 10 per cent. grading. If a man or a number of men want a water extension it will be given to them, but they have to sign an agreement that they will guarantee that the income will be 10 per cent. of the cost. They are helped out in this way, that the cost is based on a 6-in. pipe, and the department might decide as a matter of diplomatic policy to put in an 8-in. pipe. The

* Superintendent, Water Works, Troy, N. Y.

necessary fire protection is furnished and the town contributes twenty-seven dollars per year per hydrant. They have a formidable-looking document that binds his heirs and assigns forever, and it appears that some of the authorities of that town thought that they had a lien, and talked about having it filed in the courthouse in the office of record, but it was nothing but a personal agreement. It ran as far as his estate ran; but when some of these fly-by-night real estate men move out they will take their estate with them, except the real estate, and you have no claim on that. I believe with Mr. Saville that the lien on the property is the thing. Practically, it has its difficulties.

PRESENTATION DEXTER BRACKETT MEMORIAL MEDAL.

PAST-PRESIDENT WM. F. SULLIVAN. Mr. President and Members: The committee on award being unavoidably absent, it becomes my pleasing duty, on behalf of the Association, to present to the winner for this year the Dexter Brackett Memorial medal.

You all knew, or knew of, the late Dexter Brackett, who served so long and faithfully this Association, who did so much to build up the high character of the papers presented, who contributed so much to the JOURNAL, whose service to this Association was ceaseless. When Dexter Brackett passed on, you are familiar with the steps the Association took to perpetuate his memory by preparing a suitable memorial. The committee appointed performed its work with entire satisfaction to the Association. This committee believed that the memorial should take the form of service to our organization. Every year since the Memorial Fund was raised, an award of a Dexter Brackett Memorial medal has been made to one of our members, who, in the opinion of the committee appointed to judge, has presented before a meeting of this Association the best paper for the year.

I agree with the remarks of the President that this prize is within the reach of pumping-station engineers. The first memorial medal was awarded to Caleb Mills Saville. His was a practical paper by an eminent engineer. Last year it was justly awarded to David A. Heffernan, a high-grade superintendent, for his intensely practical and valuable paper. This year the committee has awarded the medal to another worthy member. The conditions of award are so eminently fair that there is no reason why this medal may not rotate from one to the other classes of our membership, provided it is won fairly. This prize award is open to all, to the engineer, the superintendent, the registrar, to the sanitarian, to the chemist, the stationary engineer, to the fireman or any member who is eligible.

Gentlemen, it is now my pleasing duty on behalf of the Association, to hand over to the winner this medal. His paper shows that he worked long and arduously, that he has given much time and thought to the preparation of this prize treatise. I might add that this Association is fortunate to have in its membership men who can and will write and present high-grade technical and practical papers which may go into the permanent records of the Association. Such a paper Mr. Robert E. Horton has written and read to us. It gives me much pleasure to present to you, Mr. Horton, the Dexter Brackett Memorial medal. [*Applause.*]

MR. ROBERT E. HORTON. Mr. President and Members of the New England Water Works Association: I believe there is an old adage to the effect that if you can think of nothing to say, say nothing, If you will kindly pardon me and allow me to get my bearings for a moment, I will

do so by telling a story, after which I wish to say something a little more serious.

I am reminded just at this moment of a small boy whom I once knew, who was very greatly interested in mechanical matters, and it was his great desire to become a carpenter. So, on his fifth birthday his parents presented him with a hammer, a plane, and a saw. He received the tools, and looked at them and said nothing. And his parents said, "Well, Johnnie, what do you think of them?" And after a moment's hesitation he said, "I am so hammered and sawed and planed that I don't know what to say." That is how I feel now.

I regret that it was not my privilege to know Dexter Brackett personally, but I am happy to say that it has been my pleasure to know many older members of the Association, some of whom have passed over the great divide. It has been my pleasure to know men older and more experienced than I, and from them — these men of the New England Water Works Association — I received the early inspiration to study the subject of rainfall.

It is not necessary to say that rainfall is very important from the viewpoint of the water-works engineer, for it is the

"Little drops of water and little flakes of snow,
Fill up the reservoirs and make the rivers flow."

In reality, we know very little of the real nature of rain, and it has been a source of pleasure to me, as I think it has been to every one who has undertaken the study of the manifestations of nature, to observe nature and its operation at work.

One of the rewards of the study of the phenomena of nature is the enjoyment of doing the work, and I believe that no one ever does any work that is worth while unless he does enjoy it. I took up the study of rainfall at a time when I was a younger man than I am now. The enthusiasm of work is not so potent in middle life as it was in the earlier days, and something is often needed to arouse enthusiasm. It seems to me that is one of the results which the Dexter Brackett medal may accomplish, and has accomplished in my own case. It affords a stimulation to further effort, because the medal carries with it the implication that our fellowmen — men who are well qualified to know of these matters — appreciate the efforts that have been made.

And so, Gentlemen, I want to thank you from the fullness of my heart for this medal. In addition to a feeling of pride at the honor you have bestowed on me, I think I feel a sense of humility when I contemplate what the efforts of one person can accomplish in comparison with the magnitude of the works of nature which are about us everywhere. In this respect, I feel very much as the Llama in Kipling's "Kim," who says:

"All Nature is one great miracle."

Gentlemen, I thank you. [*Applause.*]

PRESENTATION TO MR. WILLARD KENT, SECRETARY OF THE ASSOCIATION, 1899–1920.

The PRESIDENT. Members of the Association and Guests, Ladies and Gentlemen: Your program is just a little bit changed. We have moved from old quarters into new, driven here by the high cost of living, and I think you will agree with those whom I have consulted at the head of the board, that we have been driven into good luck. We have had as good if not a better lunch than we could have got elsewhere. We hope to find this place agreeable to all the members and to be able to gather here for some time to come.

We have a very good program to-day, and outside of the printed program we have one unusual number. We have many men sitting around our board to-day who are old members of the Association, and who have served it both as members and as officers very faithfully. Though we do not often mention their service we do not forget them, and when, after years of faithful and valuable service a man retires from office, we do not forget his work, we wish to record our appreciation of it. So, on this occasion, the Association has decided that it would note the withdrawal from the office of secretary, which he held so long and in which he did such capable and faithful work, of Mr. Willard Kent; that on this occasion we would commemorate his withdrawal, and the arrangements for the affair were placed in the hands of a committee, of which Mr. John Diven is chairman. He will explain to you just what they did, how they did it, and why it was done. [*Applause.*]

Mr. J. M. DIVEN. Ladies and Gentlemen: I suppose if I were to tell something about water-works secretaries possibly it would serve to tell Mr. Gifford some of the things he ought not to do, being rather an adept in having done the things that a secretary cannot do. Somebody has very aptly said that the principal duty of the secretary of an organization of this kind is to do all the things that are so disagreeable that nobody else wants to do them. Mr. Gifford seconds that motion already, because he has been at it a whole year and found out.

John H. Decker always claimed to be the original water-works secretary. He was the first secretary of the American Association. But Mr. Decker has passed beyond, and we will have to accord that honor to Mr. Coggeshall, who, you all remember, was the first secretary of this Association. Mr. Coggeshall served, in two different terms, twelve years as secretary; followed by Mr. Albert S. Glover, who served for three years, and was followed by Mr. Whitney. Mr. Whitney was followed by Mr. Kent, who has served twenty-one years. He is of age now.

You all attend these meetings, and if everything goes right it is right; if things go wrong it is the secretary's fault. If your lunch is not all right the secretary is to blame; if it is all right — well, it is all right, that is all. No credit to the secretary, of course. I think members very little realize the troubles and cares that the secretary of an organization of this kind has, especially as was the case with Mr. Kent, having other work to do and unable to devote his full time to it. I presume many midnight hours were devoted by him to this work.

Now, we do not want Mr. Kent to forget old times; so we wish him to have this little *timepiece* to remind him of old times, and remind him always of the time of the meetings, so that we will always see him. We do appreciate his work, though we say little about it. I wish also to present Mr. Kent with this little box filled with our appreciation of his work, with our honor for Mr. Kent, and our love for Brother Kent. [*Applause.*]

MR. WILLARD KENT. Gentlemen, I thank you. As we grow older we make fewer new friends, and the gradual slipping away of many of the old ones from various causes is one of the unpleasant experiences of life. Those that hold fast are therefore all the more appreciated. At the present time, when the spirit of change is so manifest throughout the world, I trust that, so far as it may affect the welfare of this Association, it may be for your prosperity and future success. I regret that I have not at this time the command of language adequately to express my appreciation of your kind remembrance. [*Applause.*]